THE EFFECTS OF ENGINEERING DESIGN BASED INSTRUCTION ON 7TH GRADE STUDENTS' NATURE OF ENGINEERING VIEWS AND ATTITUDES TOWARDS STEM

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submitted by **BERNA AYDOĞAN** in partial fulfillment of the requirements for the degree of **Master of Science in Science Education in Mathematics and Science Education Department, Middle East Technical University** by,

Prof. Dr. Halil Kalıpçılar
Dean, Graduate School of **Natural and Applied Sciences** ________________

Prof. Dr. Ömer Geban
Head of Department, **Math. and Sci. Edu.** ________________

Prof. Dr. Jale Çakıroğlu
Supervisor, **Math. and Sci. Edu., METU** ________________

Examining Committee Members:

Prof. Dr. Semra Sungur
Mathematics and Science Education, METU ________________

Prof. Dr. Jale Çakıroğlu
Math. and Sci. Edu., METU ________________

Assoc. Prof. Dr. Kader Bilican
Primary Education, Kırıkkale University ________________

Date: 25.07.2019

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Surname: Berna Aydoğan

Signature :

ABSTRACT

THE EFFECTS OF ENGINEERING DESIGN BASED INSTRUCTION ON 7TH GRADE STUDENTS' NATURE OF ENGINEERING VIEWS AND ATTITUDES TOWARDS STEM

Aydoğan, Berna
Master of Science, Science Education in Mathematics and Science Education
Supervisor: Prof. Dr. Jale Çakıroğlu

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The purpose of the study was to investigate the effects of engineering design-based instruction on 7th grade students' nature of engineering (NOE) views and attitudes towards STEM. The sample of the present study was 41 students of 7th grade in a public middle school in Ankara, in which 24 of them were experimental group and 17 of them were comparison group. The sample was chosen by using convenience sampling from public middle schools in Ankara. In comparison group, curriculum-based instruction was taught on "Force and Energy" topic, while engineering design-based instruction was taught on the same unit in experimental group. Quantitative research to evaluate students' nature of engineering view and attitudes towards STEM was operated through two different questionnaires as pre- and post-test. Moreover, quantitative data results were supported by analyzing change on students' nature of engineering views qualitatively. The results of the questionnaires were used for statistical analysis to analyze whether there is an effect of engineering design-based instruction on 7th students' nature of engineering views and attitudes towards STEM. The results of the study presented that there was a significant effect of engineering design-based instruction on the students' nature of engineering (NOE) views. Moreover, the results of qualitative data in the study revealed that the engineering design-based instruction developed views for various NOE aspects of the students positively. On the other hand, there was no any significant effect of the instruction on the students' attitudes towards STEM.

Keywords: Engineering Design-Based Instruction, Nature of Engineering (NOE), STEM, Attitude

ÖZ

MÜHENDİSLİK TASARIM TEMELLİ ÖĞRETİMİN 7. SINIF ÖĞRENCİLERİNİN MÜHENDİSLİĞİN DOĞASI GÖRÜŞLERİ VE STEM E YÖNELİK TUTUMLARINA ETKİLERİ

Aydoğan, Berna
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Tez Danışmanı: Prof. Dr. Jale Çakıroğlu

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Bu çalışmanın amacı mühendislik tasarım temelli öğretimin 7. sınıf öğrencilerinin mühendisliğin doğası görüşleri ve STEM'e yönelik tutumlarına olan etkilerini incelemektir. Çalışmaya Ankara ilindeki bir devlet okulunda öğrenim gören 41 7. sınıf öğrencisi katılmıştır. Çalışmanın örneklemi Ankara ilindeki devlet okulları arasından uygun örnekleme yöntemi kullanılarak seçilmiştir. Çalışmanın karşılaştırma grubunda "Kuvvet ve Eneji" ünitesi hakkında var olan öğretim programı temelli öğretim uygulanırken, deney grubunda ise aynı ünite hakkında mühendislik tasarım temelli öğretim uygulanmıştır. Nicel araştırma yöntemi kullanılarak öğrencilerin mühendisliğin doğası görüşleri ve STEM'e yönelik tutumları iki ayrı ölçeğin ön ve sontest olarak uygulanması ile belirlenmiştir. Ayrıca, öğrencilerin mühendisliğin doğası görüşlerindeki değişim nitel araştırma boyutunda incelenerek nicel araştırma yöntemi desteklenmiştir. Mühendislik tasarım temelli öğretimin öğrencilerin mühendisliğin doğası görüşleri ve STEM'e yönelik tutumlarına etkisinin olup olmadığını incelemek amacıyla istatistiksel analizler yapılmıştır. Bu çalışmanın sonuçları mühendislik tasarım temelli öğretimin öğrencilerin mühendisliğin doğası görüşlerine anlamlı etkisinin olduğunu göstermiştir. Ayrıca, nitel boyuttaki verilerin sonuçları mühendislik tasarım temelli öğretimin öğrencilerin birçok mühendisliğin doğası yönlerini positif yönde geliştirdiğini göstermiştir. Diğer yandan, sonuçlar mühendislik tasarım temelli öğretimin öğrencilerin STEM'e yönelik tutumlarına anlamlı etkisinin olmadığını göstermiştir.

Anahtar Kelimeler: Mühendislik Tasarım Temelli Öğretim, Mühendisliğin Doğası, STEM, Tutum

To my father Naim AYDOĞAN and my mother Bilgi AYDOĞAN
To my sister Seda AYDOĞAN

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CHAPTER 1

INTRODUCTION

1.1. Introduction

Knowledge and technology have gained importance in the living century in the process of time. Many changes and innovations have been made in the extent of technology and knowledge. Countries have showed economic development with these improvements and showed a great rise among other countries. When we look at the developed countries such as USA, Holland, Sweden or Germany, all these countries have great economic infrastructure. Therefore, technology and knowledge are important aspects to improve the future of a country. Besides, these developments can be helpful for daily life problems or challenges. All of them exhibit that more engineers and science experts are needed day by day because of their better skills to solve problems and to make new innovations. Accordingly, new generation students should be trained with this consciousness, and gained skills and knowledge to solve their problems that they may encounter. Nargund-Joshi, Liu, Chowdhary, Grant and Smith (2013) stated that the students should integrate their knowledge and 21st century skills (e.g., critical thinking, self-management, problem solving, time management) to different situations in their daily lives. Thus, the students should be encouraged for educational environment which integrates different disciplines for necessary knowledge, innovation qualifications and 21st century skills. In line with this purpose, recent science curriculum developments and reforms about this approach which is to help the students gain innovation qualifications in their small ages can be realized positively.

Science is the most appropriate course to train the students for innovation qualifications and 21st century skills. When objectives of 2005, 2013, 2017 and 2018

Turkish Science Curricula are examined, there are similarities between science curriculum objectives and outcomes of engineering and technology like training students who are helpful for their society and being scientifically literate person in life. However, when science education is handled independently from technology and engineering, these objectives cannot be met. Therefore, STEM (Science (S), Technology (T), Engineering (E) and Mathematics (M)) education supports the interaction among science, technology and engineering. STEM education uses real world problems based on active learning and teaching to increase motivation and academic achievement (Furner & Kumar, 2007). Many researches and studies about STEM education on students' academic achievement and motivation were studied in the science education. Yıldırım and Altun (2015) conducted a study about STEM education and concluded that students receiving STEM education are better at learning and academic achievement rather than the ones not receiving such education. Moreover, 8^{th} grade students who were trained with STEM program performed better than the ones who were not trained with STEM program on science achievement test (Olivarez, 2012). In addition to studies about academic achievement of students, Şahin, Ayar and Adıgüzel (2014) also found the positive effect of STEM education on students' motivation.

STEM education has gained importance in many countries, and they made many developments in STEM education field. Although STEM Education has an important role, its application is unfortunately weak in K-12 schools. Especially, the inclusion of engineering experiences in STEM requires greater attention in elementary level (English & King, 2015). According to the study of Deniz, Yesilyurt, Kaya, and Trabia (2017), there is similarity between nature of science (NOS), which is a major research agenda in science education, and nature of engineering (NOE). Despite unspesific description of NOS in the literature, there has been acceptable generality for the aspects of NOS among the professionals including historians of science, scientists, science educators, and philosophers of science. They argued that scientific knowledge is subjective (theory-laden); tentative (subject to change); socially and culturally embedded; empirically-based (derived from and/or based on observations of the natural world); involves human creativity and imagination. Moreover, considering the similarity between NOS and NOE, nature of engineering (NOE) should not be limited to the descriptions of engineering and engineers' works (Deniz et al., 2017). Nature of engineering should be advanced to include nature of science (NOS) aspects. These aspects are tentativeness, subjectivity, the product of human creativity and imagination, socially and culturally embeddedness, being empirically based, and being in the effect of social aspects of scientific knowledge. In their study, the researchers added demarcation criteria and engineering design process (EDP) aspects to the common list of NOS aspects and they adapted NOS research framework into the NOE research framework to assess NOE views of elementary teachers. Table 1.1. shows the descriptions of NOE aspects provided by Deniz and others (2017).

Table 1.1. *Descriptions of Nature of Engineering (NOE) Aspects*

NOE Aspect	Description
Demarcation criteria (What is engineering? What makes engineering different from other disciplines?)	Engineering is systematically engaging in the practice of design to achieve solutions for specific problems. Engineers apply their understanding of the natural world (scientific knowledge) to design solutions for real world problems. This endeavor results in new technologies.
	In the K-12 context, "science" is generally taken to mean the traditional natural sciences: physics, chemistry, biology, and (more recently) earth, space, and environmental sciences…
	We use the term "engineering" in a very broad sense to mean any engagement in a systematic practice of design achieve solutions to particular human problems. Likewise, we broadly use the term "technology to include all types of human-made systems and processes-not in the limited sense often in schools that equates technology with modern computational and communications devices. Technologies result when engineers apply their understanding of natural world and of human behavior to design ways to satisfy human needs and wants. (NRC, 2012, pp. 11-12)

Table 1.1. *Descriptions of Nature of Engineering (NOE) Aspects (cont'd)*

Engineering design process	The core idea of engineering design includes three component ideas (NGSS Lead States, 2013): Define, Design, and Optimize A. <u>Define:</u> Defining and delimiting engineering problems involves stating the problem to be solved as clearly as possible in terms of criteria for success and constraints or limits. B. <u>Design:</u> Designing solutions to engineering problems begin with generating a number of possible solutions. These potential solutions are then evaluated to assess which ones best meet the criteria and constraints of the problem. C. Optimize: Optimizing the design solution involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important.
Empirical basis	Engineers optimize their design solutions and compare alternative solutions based on evidence obtained from test data. They use assumptions to produce simplified models that does not contain the variables that the problem is insensitive to.
Tentativeness	Phases of engineering design process do not always follow in order, any more than do the "steps" of scientific inquiry. At any phase, a problem solver can redefine the problem or generate new solutions to replace an idea that is just not working out.
Creativity	Creativity and imagination of engineers play a major role during the engineering design process. The role of creativity and imagination is not limited to any specific phase of the engineering design process.
Subjectivity	There is no unique solution to an engineering design problem. While there can be many solutions to the same problem, some of these solutions may be more suited to meet the criteria and constraints of the problem.

Table 1.1. *Descriptions of Nature of Engineering (NOE) Aspects (cont'd)*

Social aspects of engineering	Engineering is not a solitary pursuit. Engineering design solutions are constructed through social negotiation. Despite their individual differences, members of an engineering community share common understandings, traditions, and values. This social dimension enhances the quality of engineering design solutions.
Social and cultural embeddedness	Engineering is a human activity. There is a continued interaction between engineering and society. Sociocultural factors influence the engineering design process, and in turn, engineering influences the society. These social and cultural factors include social composition, religion, worldview, political, and economic factors.

Source: Deniz et al., 2017

Design has essential attention in engineering education (Fan & Yu, 2017), so the understanding of engineering design processes is at the core of engineering (Cunningham & Hester, 2007). According to National Research Council (2009, 2012), there is no single design process in engineering design like scientific process, in other words, a fixed set of steps is not followed by all engineers. Wendell, Connolly, Wright, Jarvin, Rogers, Barnett and Marulcu (2010) used engineering design process that includes some steps which are "finding a problem or need", "researching possible solutions", "choosing the best solution", and "building and testing the prototype" as a frame to structure the learning process. According to these steps, in an engineering design task, firstly the students identify their prior knowledge and what they should learn more to complete this task successfully, and they research challenges and solutions for this engineering problem. Then, they choose the best solution among all possible solutions, and build and improve their designs finally. Engineering design-based activities include integration of STEM disciplines to earn targeted behaviors and skills of producing multiple solutions for engineering design problems in the daily life (Hacıoğlu, Yamak & Kavak, 2016). Thus, the students should be encouraged for educational environment which integrates different disciplines for necessary knowledge, innovation qualifications and 21st century skills.

1.1.1. Significance of the Study

Engineering education is important to foster students' understanding of engineering discipline, to improve their problem-solving skills in 21st century skills and to develop critical thinking skills with its connection to the real-world problems in addition to their learning in many areas of the curriculum (English, Hudson, & Dawes, 2013; Hynes, Portsmore, Dare, Milto, Rogers, & Hammer, 2011). Engineering design-based activities make the "engineering (E)" part of STEM education clear, and important to improve scientific literacy and inquiry-based learning by developing 21st century skills of students. Moreover, students' interests in science and engineering can be increased with teaching science by engineering design-based activities (NAE & NRC, 2014). Therefore, engineering design-based activities are necessary to support science teaching effectively.

One of the goals of STEM education is to educate "more scientifically literate citizen", but this is limited in engineering discipline in the elementary and middle schools (Stohlmann, Moore, & Roehrig, 2012). Therefore, many nations do not have a high public profile of engineering in society (English, Hudson, & Dawes, 2013) because of a lack of knowledge about engineering discipline (National Grid, n.d.). The result of the study presented that students' confidence in science and engineering subjects continues to decline as they grow in age (Knight & Cunningham, 2004). This situation has also encountered in Turkey. In 2017 Turkish Science Curriculum, "Science and Engineering Application" was added as a new unit in each grade level to make "engineering (E)" part of STEM education clear (MEB, 2017). Then, "Science, Engineering and Entrepreneurship Applications" were integrated in each grade level in 2018 Turkish Science Curriculum by revising 2017 Turkish Science Curriculum to improve students' engineering and design skills (MEB, 2018). Within the context of 2018 Science Curriculum regulation, beginning from 4th grade, the students are expected to make activities as part of "Science, Engineering and Entrepreneurship" by considering their daily life problems. However, engineering design-based activities are integrated in each grade level; in other words, there are objectives in science, mathematics and technology disciplines of STEM education in Turkish science curricula, but objectives in engineering discipline are not emphasized clearly.

Despite the importance of engineering education, research on engineering is a new research field and the emphasis of elementary education in elementary classrooms is not desirable (Yeşilyurt, Deniz, & Kaya, 2019). In addition, some misconceptions of students about engineering concepts affect their learning in engineering concepts negatively. For example, students' views about engineers are limited in fields of fixing and building because they consider engineers as mechanics, laborers and technicians (Knight & Cunningham, 2004; Fralick, Keam, Thompson, & Lyons, 2009). Thus, instructions should be developed to eliminate students' misconceptions about engineering discipline. In addition, the students and teachers' nature of engineering views were developed positively with explicit NOE instruction and engineering design experience (Yeşilyurt, Deniz, & Kaya, 2019; Deniz et al., 2017). Deniz and others (2017) considered the similarity between NOS and NOE aspects and used NOE research framework, which was prepared by adding demarcation criteria and engineering design process (EDP) aspects to the common list of NOS aspects, to assess elementary teachers' NOE views. Moreover, design is the important aspect of engineering education (Fan & Yu, 2017), so students' nature of engineering views can be developed more with understanding of engineering design processes which is one of the aspects of NOE. Nature of engineering (NOE) research is still a new research area in the literature, so there are limited studies about nature of engineering (NOE) views of students and teachers. According to English and King (2015), there have been extensive researches about engineering-based programs with older learners in the literature, but more researches are needed with younger learners because of the positive effect of such programs on younger learners' development. This limited research with younger learners may be caused from the view in which design processes can be a complex for younger learners. However, the result of previous study showed that younger learners have an emerging capacity for simple design work (imagining, planning, constructing, and evaluating) (as cited in English & King, 2015). Therefore, in the present study, change in 7th grade students' NOE views with engineering design-based instruction were examined by emphasizing the engineering design process (EDP) aspect of NOE during the "Force and Energy" unit. Moreover, NOE categorization schema which was formed by the researcher based on NOS categorization schema (Bilican, 2014) because of similarity between NOS and NOE aspects was used in the present study as different from the previous study conducted by Yeşilyurt and others (2019). Therefore, the impact of engineering design-based instruction on 7th grade students' views about nature of engineering aspects was analyzed in detail with NOE categorization schema by categorizing students' NOE views as "informed", "adequate", or "inadequate".

Besides, researches showed that numbers of students who study post-compulsory science and mathematics decrease around the world (as cited in McDonald, 2016). The reason of this decline focuses on students' motivation towards mathematics and science because of the transition from primary school to high school (McDonald, 2016). Motivated students have better academic success by asking questions, participating in labs, and making cooperative learning (Schunk, Pintrich, & Meese, 2008), so they must get activities and courses that are meaningful for their personality (as cited in Chumbley, Haynes, & Stofer, 2015). Integration of engineering in curriculum increases students' academic achievement, 21st century skills, motivation towards science learning and attitudes towards STEM (Moore et al., 2015). In the literature, there is also the lack of enough study about whether and how participating in engineering design-based science education in formal science classrooms change student attitudes towards science and engineering (NAE & NRC, 2014). In addition, there is a limited study and research about the effect of engineering design-based instruction on students' attitude towards STEM. For these reasons, there is a need for more studies investigating the effects of engineering design-based instruction on students' attitude towards STEM. In the present study, the effects of engineering design-based instruction were examined by emphasizing the engineering design process (EDP) aspect of NOE during the "Force and Energy" unit to improve students' attitudes towards STEM.

1.1.2. Definition of Important Terms

The definitions of the important terms used in the present study are presented in this section.

Nature of Engineering: Lederman (1992) described nature of science (NOS) as a way of knowing, the epistemology of science, and the values and beliefs which are constitutional issues for the development of scientific knowledge, and there have been acceptable generality for the aspects of NOS; tentativeness (subject to change), subjectivity (theory-laden), socially and culturally embedded, empirically-based (based on and/or derived from observations of the natural world), involving human creativity and imagination. Deniz and others (2017) emphasized the similarity between NOS and nature of engineering (NOE) aspects; tentativeness, subjectivity, the product of human imagination and creativity, socially and culturally embeddedness, being empirically based, and being in the effect of social aspects of scientific knowledge.

Engineering Design-Based Science Education: Engineering design-based science education is teaching approach which includes integration of STEM disciplines to earn targeted behaviors and skills of producing solutions for engineering design problems in the daily life (Hacıoğlu, Yamak & Kavak, 2016). It is important to foster students' understanding of engineering discipline, to improve their problem-solving skills in 21st century skills and to develop critical thinking skills with its connection to the real-world problems in addition to their learning in many areas of the curriculum (English, Hudson, & Dawes, 2013; Hynes, Portsmore, Dare, Milto, Rogers, & Hammer, 2011).

Engineering Design Process: There have been similarities between scientific inquiry and design, and they are referred to as procedures to solve problems and both emphasize learning by doing. Scientific inquiry includes the characteristics of the development process for scientific knowledge; involving observations and scientific investigations with sharing a common set of deductive and inductive reasoning, examining various sources of information, having no fixed sequence of steps of scientific method etc. Similarly, design does not also have generalized design method, but such elements which are posing, generating, evaluating and choosing solutions are shared by various of methods to solve ill-defined problems. The engineering design process, which can be defined as the production process of technologies; provides the integration of STEM disciplines because it requires the use of basic engineering knowledge and skills as well as the principles of science and mathematics (Householder & Hailey, 2012; NAE & NRC, 2009). There are many different design processes in the literature, but in all these processes, there are similar expectations such as the definition of the problem, revealing the possible solutions, analyzing, testing and evaluating the solutions and renewing the solution if necessary (Brunsell, 2012).

STEM Education: The word of STEM is the shortening of first letters of Science (S), Technology (T), Engineering (E) and Mathematics (M), and there is no standard explanation of STEM in the literature (Altaş, 2018). STEM education is a teaching system aiming at integrating science, engineering, technology, and mathematics disciplines with each other (Bybee, 2010). Collaboration of these disciplines of STEM education in both interdisciplinary and in disciplines supplies the integration of courses with each other rather than using these disciplines separately.

Attitude Towards STEM: One of the major goals of K-12 STEM education in U.S. is to develop students' attitudes towards STEM (Guzey, Harwell, & Moore, 2014). Burke and Mattis stated that economical growth, the stability and security of the nations, and citizens health needs the progress of knowledge, and attitudes towards STEM fields (as cited in Popa & Ciascai, 2017). Moreover, students' learning and motivation to learn STEM subjects can be affected from their attitudes (Osborne, Simon & Collins, 2003; Guzey, Harwell, & Moore, 2014).

1.1.3. Purpose of the Study

The purpose of the present study was to investigate the effects of engineering design-based instruction on 7th grade students' nature of engineering (NOE) views and attitudes towards STEM. Regarding the literature in the present study, nature of engineering (NOE) views and attitudes towards STEM of the students receiving engineering design-based instruction (EDBI) and others receiving curriculum-based instruction (CBI) were identified in both before and after the instructions. Statistical analysis was conducted to see the effect of EDBI over CBI on 7^{th} grade students' nature of engineering (NOE) views and attitudes towards STEM. Moreover, how engineering design-based instruction causes change in NOE aspects of 7^{th} grade students' nature of engineering (NOE) views was analyzed qualitatively to support quantitative research.

Firstly, in the present study, it was hypothesized that there is significant difference between the students receiving engineering design-based instruction (EDBI) and others receiving curriculum-based instruction (CBI) with respect to students' nature of engineering (NOE) views. Participants improved their views of various NOS aspects after receiving an explicit instruction of NOS as resulted in previous researches (Bell, Matkins, & Gansneder, 2011; Akerson, Morrison, & McDuffe, 2006). Therefore, by considering the similarity between NOS and NOE as stated by Deniz and others (2017), the students receiving engineering design-based instruction were expected to improve their NOE views more than others receiving curriculum-based instruction.

Secondly, it was hypothesized that there is significant difference between the students receiving engineering design-based instruction (EDBI) and the students receiving curriculum-based instruction (CBI) with respect to students' attitudes towards STEM. Integration of engineering in curriculum increases students' academic achievement, 21st century skills, motivation towards learning science and their attitudes toward STEM (Moore et al., 2015). Therefore, the students receiving engineering design-based instruction were expected to improve their attitudes towards STEM more than others receiving curriculum-based instruction.

1.1.4. Research Questions

1. What is the effect of engineering design-based instruction (EDBI) over curriculum-based instruction (CBI) on 7th grade students' nature of engineering (NOE) views in Ankara?
2. How does engineering design-based instruction (EDBI) impact 7th grade students' views about nature of engineering aspects (NOE) in Ankara?
3. What is the effect of engineering design-based instruction (EDBI) over curriculum-based instruction (CBI) on 7th grade students' attitudes towards STEM in Ankara?

CHAPTER 2

LITERATURE REVIEW

In literature review chapter, the review of the literature regarding STEM Education, STEM Education in Turkey, nature of engineering (NOE), and engineering discipline in 2013-2017 and 2018 Turkish Science Curricula and attitude towards STEM are presented.

2.1. 21st Century and Integration of Technology and Engineering in The Context of Science Education

Knowledge and technology have gained importance in the living century in the process of time. Many changes and innovations have been made in the extent of technology and knowledge. Countries have showed economic development with these improvements and showed a great rise among other countries. When we look at the developed countries such as USA, Holland, Sweden or Germany, all these countries have great economic infrastructure. Therefore, technology and knowledge are important aspects to improve the future of a country. Besides, these developments can be helpful for daily life problems or challenges.

All of them exhibit that more people who are interested in the fields of engineering, mathematics, science and technology are needed day by day (Miaoulis, 2009; Ercan, 2014). These people should have better skills to solve daily life problems, to make new innovations, and to improve critical thinking skills, creativity etc. Therefore, most countries started many educational reforms and increased their attention towards the fields of science, engineering mathematics, and technology. There was STEM education which has increasing popularity day by day at the center of science education reforms.

2.1.1. Science, Technology, Engineering and Mathematics (STEM)

The term of STEM was firstly used by Judith Ramaley in 2001 (Altaş, 2018). Although the word of STEM is the shortening of first letters of Science (S), Technology (T), Engineering (E) and Mathematics (M), there is no standard explanation of STEM in the literature (Altaş, 2018). For example; Gonzalez and Kueenzi (2012) described STEM as the first letters of these four different disciplines in their study. STEM is an interdisciplinary area because of making a bridge between these four disciplines (Meng, Idris & Eu, 2014).

2.1.1.1. Science

Science is based on the facts assumed to be claims about the world we live in. What we can see, hear and touch are the bases of science rather than personal opinions about the world (Chalmers, 1999).

2.1.1.2. Technology

Technology is defined as the used information or knowledge and developing process of a product (Bozeman, 2000). Lan and Young (1996) described that technology is to obtain certain results, to solve problems, to complete certain tasks.

2.1.1.3. Engineering

Engineering is a process of people working on science and mathematical principles by using their opinions, experiences and decisions to create helpful products for humans to make their life easier (NRC, 2012).

2.1.1.4. Mathematics

Mathematics is about finding new ideas and solving everyday problems by using imagination, intuition and reasoning (Khan, 2015).

2.1.2. STEM Education

When the literature about STEM education has been analyzed, there has no any standard explanation of STEM education like STEM explanation. Researchers has different ideas and explanations about it in the literature.

The need of 21st century societies for science and technology literate citizens generated a consensus on the need for students to develop knowledge and skills in science, engineering, technology, and mathematics through education. However, they are mostly included in the curriculum in science and mathematics K-12 level (NAE, 2010). Therefore, Bybee (2010) stated that technology and engineering disciplines should be included in the curriculum because this situation was one of the obstacles for STEM education. STEM education is a teaching system aiming at integrating science, engineering, technology, and mathematics disciplines with each other (Bybee, 2010). Collaboration of these disciplines of STEM education in both interdisciplinary and in disciplines supplies the integration of courses with each other rather than using these disciplines separately. Moreover, STEM education approach states that the boundaries between disciplines are removed and require an integrated education (Roberts, 2012). Students' conceptual knowledge about the nature of science (NOS) and mathematics to gain their understanding of technology and engineering has been supplied with STEM education (Hernandez, Bodin, Elliott, Ibrahim, Rambo-Hernandez, Chen, & de Miranda, 2014). Moreover, one of the purposes of STEM education is to train STEM literate person (Pekbay, 2017). According to Balka (2011), STEM literate person can define, perform, and combine concepts from four disciplines which are science, technology, engineering and mathematics to understand and solve complex problems in their daily life. Therefore, STEM education gives opportunities people to be more productive and to gain 21st century skills which are critical thinking, communication, problem solving etc. (Pekbay, 2017). It can be concluded that the integration of STEM concepts in real-life problems needs to be developed (Asghar, Ellington, Rice, Johnson & Prime, 2012).

Although integrated program emphasizing all disciplines of STEM is the most appropriate approach to the nature of STEM education, it is not possible to realize this in the context of practical applications in formal education. The present structure of schools and curricula is not suitable for the mentioned integration in terms of achievements, scope, teaching activities and evaluation approaches (NRC, 2012; Bybee, 2010; NAE & NRC, 2009). This situation results in handling STEM education in different forms. According to Sanders (2009), focusing on one or two disciplines of STEM disciplines is one of the ways of handling STEM education. Dugger (2010) stated "SteM" as putting technology and engineering into the background, but expectations toward STEM education cannot be met with this approach emphasizing technology and engineering merely (as cited in Bybee, 2010). Another approach about STEM education is integration of one discipline of STEM to other disciplines separately. For example, integration of engineering to science, mathematics and technology courses. However, conversely, integration of other disciplines to one discipline of STEM is more appropriate approach for STEM education. Integration of engineering, mathematics and technology to science course can be an example for this approach (Dugger, 2010). Moreover, Bybee (2010) expressed that integration of other STEM disciplines which are engineering and technology to mathematics and science courses included in K-12 level curricula is the most plausible way for this approach. Therefore, integration of STEM disciplines has been actualized within the scope of engineering design problems in science education in this approach (Roth, 2001).

2.1.2.1. STEM Education in Turkey

When we focus on interdisciplinary approach of STEM in Turkey, Yamak, Bulut and Dündar (2014) stated that STEM education is the integration of skills and knowledge in science, engineering, mathematics and technology. In the study of Yıldırım and Altun (2014), STEM education was stated as an education approach which supplies qualified and effective learning, uses learned knowledge in daily life, improves high-level thinking skills by integrating disciplines of science, engineering, mathematics and technology. Moreover, The Ministry of Education described STEM education in

STEM education report as a teaching system which includes integration of science, engineering, mathematics and technology disciplines by making connection among them (MEB, 2016a).

The most important developments in Turkish science curriculum was resulted from changes in 2005 and 2013 science curricula by The Ministry of Education. These new curricula were prepared depending on constructivist approach, in which learners construct their own learning and understanding of the world where they live, and they interpret them based on their previous knowledge, perceptions of social experiences, and beliefs, by focusing student-centered learning (MEB, 2005; MEB, 2013). In 2013 Turkish Science Curriculum, there were objectives in science, technology and mathematics disciplines of STEM education. Although the vision of the updated versions has similar characteristics with the 2013 Turkish Science Curriculum, some additions were examined in the 2017 and 2018 Turkish Science Curricula. Among these additions, it was emphasized that the science should be combined with other disciplines in the programs and that students should apply the knowledge and skills they learned in theory for the product and process (MEB, 2017; MEB, 2018). In addition, "science, engineering and entrepreneurship applications" and "engineering and design skills" were added to these curricula (MEB, 2017; MEB, 2018). By considering these additions to the science curriculum, although there were no objectives in engineering discipline in 2005 and 2013 Turkish science curriculum, 2017 and 2018 Turkish science curricula emphasized obejectives in engineering discipline clearly. For example, 7th grade students are expected to design a product to decrease air and water resistance by using their knowledge based on the objective which is "Design a product to decrease air and water resistance".

2.1.3. Studies about STEM Education

In this section, the researches about STEM education was included as a result of the literature review. STEM education which is an interdisciplinary approach of four disciplines (science, technology, engineering and mathematics) uses real world problems based on active learning and teaching to increase motivation and academic achievement (Furner & Kumar, 2007). There are many researches and studies about STEM education.

Olivarez (2012) investigated the impact of STEM educational program on 8th grade students' academic achievement in the study. STEM educational program consisted of hands-on group activities about designing a project to solve real world problems. Research group was formed with a total of 176 8th grade students in which 73 students trained with STEM program, and 103 students did not involve any STEM program. Results of the study showed that students trained with STEM program performed better than ones who were not trained with STEM program on achievement tests of science, mathematics and reading.

In a similar study by Tati, Firman and Riandi (2017), 8th grade students' STEM literacy was investigated with STEM learning through designing a project. A total of 56 8th grade students were assigned in experimental and comparison groups as being 28 students in each group. In experimental group, project-based learning treatment with STEM approach was instructed while such treatment without STEM approach was instructed in comparison group. The students designed a boat model in energy topic through STEM learning in experimental group. Data were collected with STEM literacy test consisting of science literacy, mathematics literacy, and technology-engineering literacy as pre and post tests in both groups. The result of the study presented that STEM literacy of the students receiving project-based learning treatment with STEM approach was significantly improved more than others in comparison group because of designing an engineering activity in which the students applied the knowledge from every field of STEM.

Cotabish, Dailey, Robinson and Hughes (2013) investigated the effects of the STEM program on elementary students' content and concept knowledge, and science process skills. Firstly, 70 teachers were randomly assigned in experimental and comparison groups, and the teachers of experimental group participated in a one-week-long summer course about professional development and one-to-one peer coaching focusing on skills and knowledge in science while others did not receive any instruction. Then, 818 elementary students were assigned to experimental and comparison teachers, and the students of comparison group received science instruction using the school-adopted science curriculum while others in experimental group received instruction in one William and Marry inquiry-based curriculum by experimental teachers. This curriculum consisted of units focused on engaging the students in creative and critical thinking, and real-world problem solving. The results of the study presented that the students receiving STEM program significantly performed better in their science process skills and science content and concept knowledge than others in comparison group.

Moreover, there are researches about the effect of STEM education in Turkey. Yamak and others (2014) studied 5th grade students' attitudes towards scientific process skills and science through STEM activities. Researchers studied with 20 5th grade students during three different STEM activities. These STEM activities were prepared based on the steps of design-based learning; explanation of the assignment and giving materials by the teacher, planning a design of the students in groups, testing their models and evaluation etc. Data were collected from 20 students during pre and post-tests by using two different instruments which are “What Do I Really Think About Science Survey” and “Scientific Process Skills Test” to analyze their attitudes towards science and scientific process skills. As a result of the study, they stated that participating STEM activities led to a positive increase in students’ attitudes towards science, scientific process skills, self-confidence.

The research by Baran, Canbazoğlu-Bilici and Mesutoğlu (2015) indicates the effect of STEM public service announcement within the scope of engineering design process on knowledge and skills about technology and computer. In STEM public service announcement, the students were expected to design a STEM spot about a scenario provided them. 6th graders participated to STEM training program in Middle East Technical University, and they designed a STEM public service announcement shown in TV channels by following engineering design process with the help of computers with internet connection in 160 minutes. The result of the study indicated that STEM education results in increase on students' knowledge, skills, interest towards STEM fields and motivation.

In addition to studies about academic achievement of students, Şahin, Ayar and Adıgüzel (2014) also found the positive effect of STEM education on 9th grade students' motivation. In the study by Akdağ and Güneş (2017), teachers and science high school students' opinions about STEM activities on the subject of energy were analyzed. A total of 30 9th grade students joined STEM activities during 6 weeks within the context of physics lesson, and the subject of energy was taught to students with STEM activities. As a result of the study, STEM activities contributed to students' motivation and learning levels, and the opportunity to transfer the knowledge learned.

In a similar research studied with preservice science teachers, Yıldırım and Altun (2015) searched academic achievement of preservice science students during science laboratory lessons in the result of STEM education and engineering applications. 83 preservice science teachers studied at 3th grade of university were joined to the research. Some of these students studied in experimental group in which engineering applications and STEM education were applied during science laboratory lessons, while others studied in control group and did not trained with STEM education in science laboratory lessons. According to the results of the study, learning and academic achievement of preservice science teachers receiving STEM education are better rather than the ones who are not trained with such education.

2.2. Nature of Engineering

The concept of engineering, which is used for finding solutions for people's problems, is expressed as an occupation based on academic disciplines like mathematics and science (Petroski, 1996). From an early age, students have stereotyped misconceptions about the engineering profession. In general, the fact that an engineer is seen only as a construction worker, as a repairer, and considering the engineer profession as a male-specific profession cause them to create misconceptions against engineers and engineering from an early age (Fralick et al., 2019). Although mathematics, science, and even technology disciplines included in the STEM education approach have a long history in the K-12 curriculum and their teaching standards are defined, this is not the case for engineering discipline (NAE & NRC, 2009). However, Wicklein (2003) suggested that focusing on engineering rather than technology at the K-12 level would be a more effective strategy. The aim of engineering education is to enable students to produce practical and analytical solutions to the problems they may face in their daily life, to develop their design skills in this training process, and to ensure that they use their designs in the most effective way (Kolodner, 2002; Akgül, Uçar, Öztürk & Ekşi, 2013).

In recent years, reforms have been made about engineering discipline of STEM education in K-12 schools in many developed countries like USA to develop students' design-based competencies and technological literacy (Cajas, 2001). Many engineering programs and elective engineering courses were developed. The first step in this direction can be described as including the engineering objectives as well as the science and technology as stated in the report which defines the teaching standards published by the Massachusetts Department of Education (MDOE) in 2001. Under current circumstances, taking engineering discipline as an independent course in K-12 curricula requires fundamental changes in the school structure, so the integration of engineering discipline to science, mathematics and technology disciplines with appropriate activities is seen as the most appropriate way for K-12 engineering education (NAE & NRC, 2009). In addition, engineering design-based science education have been considered to support the integration of engineering discipline to science education (Ercan, 2014). Engineering design-based science education is teaching approach which includes integration of STEM disciplines to gain targeted behaviors and skills of producing solutions for engineering design problems in the daily life (Hacıoğlu, Yamak & Kavak, 2016). In this process, the engineer actively uses science concepts and builds an understanding of these concepts while trying to find solutions to the problems (Altaş, 2018).

Deniz and others (2017) defended that nature of engineering (NOE) should not be limited to the descriptions of engineering and engineers' work and emphasized the similarity between NOS and NOE aspects. These aspects are tentativeness, subjectivity, the product of human creativity and imagination, socially and culturally embeddedness, being empirically based, and being in the effect of social aspects of scientific knowledge. In their study, they adapted NOS research framework into NOE research framework to assess elementary teachers' NOE views by adding demarcation criteria and engineering design process (EDP) aspects to the common list of NOS aspects. Deniz et al. (2017) described each NOE aspect as explained below.

2.2.1. Demarcation Criteria

Demarcation aspect of NOE corresponds to question of what engineering is and what engineering makes different from other disciplines. Engineering is engaging solutions for specific problems in daily life and inviting new technologies by applying their scientific knowledge (Deniz et al., 2017).

The public has partial view of engineer and engineering. Drawings can be a clue for children's conceptions (Kress & Leeuwen, 2001). Therefore, Knight and Cunningham (2004) stated that understanding students' images about engineer and engineering is important for theoretical and practical implications because individuals' view about the world can be shaped by the images. The authors developed a "Draw an Engineer Test" (DAET) to assess images of students' view about engineer and engineering and administered this questionnaire at the beginning of any unit on engineering. A totatl of 253 students (73 students in grades 3-5; 41 students in grades 6-8; and 139 students in grades 9-12) were participated to the study. In the DAET, there are some questions about what engineering is, what engineers do, picture of an engineer at work, familiar engineers in their life. Pictures which were translated into codes and written responses were analyzed by developing codes of recurring themes. The result of the study showed that drawings of the students showed considerable evidence for the themes of images about building/fixing and designing without any intervention. In addition, the results showed the effect of working with two female undergraduate engineering students in the students' drawings because their drawings presented that significant difference in the number (22 % of difference) between a female and male engineer. There was mostly a female engineer than male because of working with the female engineering students for a few months before the research (Knight & Cunningham, 2004).

Chou and Chen also studied Chinese version of the "Draw an Engineer Test" (CDET) to assess elementary school students' views of engineers in Taiwan. A total of 750 students (grades 4-6) from different school districts voluntarily participated to the study. In the quantitative part of the study, students' drawing about engineer was analyzed by a content analysis method. In the questionnaire, drawing instructions about an image of an engineer and short-answer questions about giving a name to the drawn engineer, the place of the engineer works, and what the engineer does in the drawing. The drawings of the students were coded by two elementary school teachers who were experienced in grading students' artworks according to the coding principles which are stereotypes of engineers, types of engineers (electrical-engineering related, architectural-engineerin relatedetc.), conceptions of engineering (laborer/mechanic, technican etc.), and engineering epistemology). The results of the study showed that engineering was accepted as male professional by 80% of the students, approximately 73% of the students drawed engineers as working at construction sites, 55% of the students conceived engineers as laborer or mechanics, and 73% of them presented lack of knowledge of engineering.

2.2.2. Engineering Design Process

Next Generation Science Standards (NGSS) recognized that engineering design and thinking are major components of K-12 engineering education and highlighted the interrelated nature of science (NOS) and engineering education (English, 2016). Lewis stated that both scientific inquiry and design are referred to as procedures to solve problems and identified similarities and differences between inquiry and design (as cited in Purzer, Goldstein, Adams, Xie & Nourian, 2015). Scientific inquiry involves observations and scientific investigations with sharing a common set of deductive and inductive reasoning. Besides, it has no fixed sequence of steps of scientific method throught scientists' studies of the natural world and examines various sources of information. Similarly, design does not also have generalized design method, but such elements which are posing, generating, evaluating and choosing solutions are shared by various of methods to solve ill-defined problems. Moreover, both emphasize learning by doing. Scientific inquiry has a process of transformative learning in which both teacher and students express their ideas, and in designing, individuals brainstorm and make prototypes, rehearsal aand get feedback from failure, draw and make connection with materials and ideas of different people (as cited in Purzer et al., 2015). However, according to Lewis (2006), there were also some divergences between scientific inquiry and design as well as similarities. They are different in the role of constraints (design reasoning includes constraint), the role of trade-offs (no parallelity of this form in science) and the role context (context shape the design problems while context is overreached in science problems) (as cited in Purzer et al., 2015).

In the report entitled "Engineering in K-12 Education: Understanding the Situation and Meeting the Expectations", design is shown as the most important dimension of engineering (NAE & NRC, 2009). The design expressed as the problem-solving approach of the engineers in the most basic sense in the context of engineering is a process that begins with the definition of the problem and ends with the solution that meets the constraints and criteria defined for the desired performance (NAE & NRC, 2009). Moreover, the engineering design process, which can be defined as the production process of technologies; provides the integration of STEM disciplines because the basic engineering knowledge and skills are required as well as the principles of mathematics and science (Householder & Hailey, 2012; NAE & NRC, 2009). For this reason, the engineering design process is defined as a pedagogical tool that provides real life context for STEM education approach and enables the realization of meaningful learning and integrates other STEM disciplines in the context of science education. (Felix, Bandstra & Strosnider, 2010). The engineering design process provides individuals opportunity to practice their knowledge of science and math as well as gaining competence and confidence (Çavaş, Bulut, Holbrook & Rannikmae, 2013).

There are many different design processes in the literature, but in all these processes, there are similar expectations such as the definition of the problem, revealing the possible solutions, analyzing, testing and evaluating the solutions and renewing the solution if necessary (Brunsell, 2012). Wendell et al. (2010) used engineering design process that includes some steps which are "finding a problem or need", "researching possible solutions", "choosing the best solution", and "building the prototype" and "testing the prototype" as a frame to structure the learning process (Figure 2.1.). According to these steps, in an engineering design task, firstly the students identify their prior knowledge and what they should learn more to complete this task successfully, and they research challenges and solutions for this engineering problem. Then, they choose the best solution among all possible solutions, and build and improve their designs finally. Moreover, engineering design problems which are inherently creative do not reflect a linear process indicating sequence of implementation of steps (NAE & NRC, 2009). Therefore, students can gain opportunities for the application of the knowledge gained in different situations as well as an learning environment for science content, and for engaging in the practices of engineers and scientists (as cited in Marulcu & Barnett, 2015).

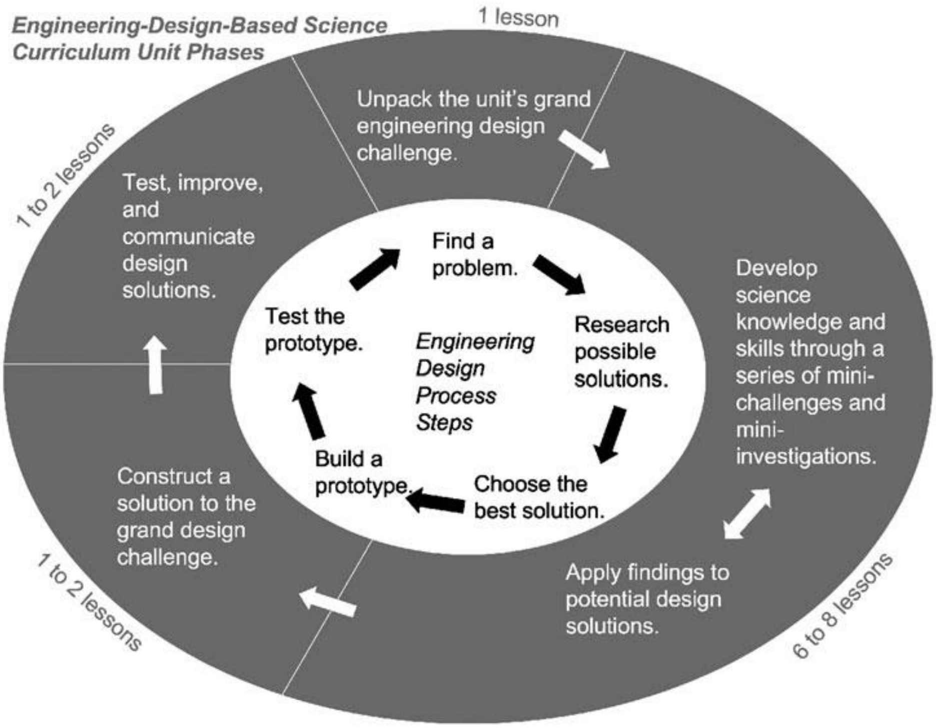

Figure 2.1. *The engineering-design process consists of five steps: finding/identifying a problem, researching possible solutions, choosing the best solution, building a prototype, testing the prototype and repeating steps as needed*

Source: Wendell et al., 2010, p. 92

2.2.2.1. Finding a Problem or Need

Engineering design process generally starts with a need, desire or problem (Ercan, 2014). At this stage, engineers try to identify the criteria and constraints forming the solution for the final product or system to better identify the problem by asking questions (Brunsell, 2012). The criteria, described as the qualifications that the successful solution should have, reflect expectations of users in function, efficiency level, durability, cost etc. of a product or system. The constraints are limitations such as legal, social, moral, aesthetic, economic etc. that engineers should consider when performing design solutions (Ercan, 2014).

2.2.2.2. Researching Possible Solutions

Individuals offer different solutions for the given problem. For the product or system to be successful, individuals search for existing solutions, collect experimental data and brainstorm for alternative solutions (Ercan, 2014; Altaş, 2018). A single correct solution cannot be mentioned for engineering design problems, so engineering must be a creative effort (NAE & NRC, 2009; NAE, 2010).

2.2.2.3. Choosing the Best Solution

Although there are various ways to meet the criteria and fulfill the constraints in engineering design problems, designing the best solution is the aim of engineering (NRC, 2012). Individuals analyze and evaluate many solutions they propose within the framework of design criteria and constraints after their research and brainstorming. What is important is to choose the solution that best meets the criteria and constraints (Ercan, 2014). In this respect, individuals can benefit from two situations in determining the best solution. More preferred is to design a new solution that suitably combine the strengths of possible solutions. In cases where this is not possible, decideing the most appropriate one among the existing conditions by comparing the advantages and disadvantages of the possible solutions (Mentzer, 2011; NRC, 2012).

2.2.2.4. Building and Testing the Prototype

At this stage of engineering design process, individuals design their prototypes to visualize, present, reveal details and advance their designs (Tayal, 2013). The prototype is a representation of the final solution or a physical, virtual, mathematical model (Hynes et al., 2011). Individuals design their prototype by putting into practice of knowledge in the theory they learned and considering the limitations and success criteria at the design stage (Altaş, 2018). Prototypes are tested and evaluated by considering the constraints and criteria (Hynes et al., 2011). The purpose of the evaluation is to see the functionality of the prototype for the solution of the problem situation and if there are deficiencies in the prototype made, it is done to eliminate it (Altaş, 2018).

2.2.3. Tentativeness

There is no following order in the steps of engineering design problems and a problem solver can go back at any phase. For example, the problem can be re-defined or new solutions can be generated to replace nonworking idea (Deniz et al., 2017)

2.2.4. Creativity

A problem solver's imagination and creativity play a major role of at any step of engineering design process (Deniz et al., 2017).

2.2.5. Subjectivity

Engineering design problem does not have an unique solution in other words many solutions can be found to the same problem because of problem solvers' pre-conceptions, values and background (Deniz et al., 2017).

2.2.6. Social Aspects of Engineering

Social negotiation is effective in the construction of engineering design solutions, so the quality of engineering design solutions can be enhanced with this effect. Despite problem solvers have individual differences (pre-conceptions, values and background), traditions, common understandings and values are shared by members of an engineering community (Deniz et al., 2017).

2.2.7. Social and Cultural Embeddedness

Engineering is a human activity, so there is influence of socio-cultural values (religion, political and economic factors, worldview etc.) on engineering design solutions, and in turn, engineering design solutions influence socio-cultural values of a society (Deniz et al., 2017).

2.2.8. Research on Engineering Design-Based Science Education

Integration of engineering in curriculum increase students' academic achievement, 21st century skills, motivation towards learning science and their attitudes toward

STEM (Moore, Tank, Glancy & Kersten, 2015). Students' interest in science and engineering can be increased by teaching science with engineering design-based science education (NAE & NRC, 2014).

In addition, Guzey, Moore, Harwell and Moreno (2016) searched 7th grade students' learning and attitudes towards STEM in the result of training with engineering design-based science curriculum. Participants of the study were three middle school life science teachers and summer professional development program in which they learnt about engineering design and developed a design-based unit together was applied for 3-week-long. The unit was prepared based on eight practices of science and engineering practices; define problems, develop and use models, plan and carry out investigations, analyze and interpret data etc. Then, 275 students of 7th grade were implemented the prepared curriculum unit by these trained teachers. Data were collected with a content test to assess students' understanding in engineering, science and mathematics disciplines, and with attitude survey to assess students' attitudes towards STEM in both before and after the engineering-based curriculum unit. The result of the study showed that there was statistically significance increase on students' academic success in science concepts and attitudes towards STEM after receiving engineering-based curriculum unit.

In other study by English, King and Smeed (2017), the effect of engineering design on 6th grade students' STEM learning was investigated with a total of 136 6th grade students. The activity was about an engineering-based problem on earthquakes based on engineering design processes and using STEM disciplinary knowledge to solve the problem. They planed their designs of earthquake resistant building, sketched, constructed and tested them by considering limilations and constraints. Data were collected from different instruments which are audio and video recordings from selected focus group in their solving the earthquake problem and designing their models, students' activity booklets, and their building models. The resut of the study showed that the students presented engineering techniques and core STEM concepts in their responses.

English, Hudson and Dawes (2013) investigated a study about the effect of STEM activity through engineering design on 4^{th} grade students' learning and working on an aerospace problem. A total of 63 4^{th} grade students participated to the study, and they followed engineering design process steps (deciding a problem, idea generation, designing a model, testing, and redesign) in working an aerospace problem, which is designing a 3-D model plane by using their mathematics and science knowledge. Data were collected from audio and video recordings during engineering design process steps in class, students' workbooks and photos of the students' final plane models. The result of the study presented that following engineering design process allowed the students to apply their disciplinary knowledge in solving an aerospace problem successfully, and also better integration of STEM disciplines.

In a similar study by English (2018), the effect of the activity integrated with STEM problem which is not predetermined problem on 4^{th} grade students' learning with a focus on design. A total of 34 4^{th} grade student participated to the STEM activities in which they linked their learning in STEM disciplines to the application of design processes (deciding their own problem and design aims, drawing their designs, testing, and redesigning). The students designed and constructed their own shoes by considering the role of designers and engineers in shoe manufacture and materials. Data were collected through audio and video recordings of the students' interactions in designing their shoes and whole class discussions, and workbook of each student and their shoe designs. The result of the research presented that the students was better than expected as beginning designers, in other words they showed advanced inquiry processes, representational skills, and STEM-based conceptual development.

In another study, Purzer and others (2015) found the same positive effect of engineering design-based science education on learning of high school students. The participants were 63 high school students, and they participated in a project in which they designed energy-efficient solar buildings by using existing buildings in a computer-aided design program for five courses. Data were collected through design replays (students' design actions while sketching buildings, collecting data etc.) and electric notes taken by the students while designing which are collected in computer software program. The result of the study indicated that the students had opportunities for meaningful science learning by participating engineering design activity and they also explore and develop scientific explanations.

The results of the previous studies showed that activities based on engineering design process have developed students' decision-making skills, scientific process skills and academic achievements (Bozkurt, 2014; Gencer, 2015; Yıldırım & Selvi, 2017). Roth (2001) carried out the study with a total of 26 students about simple machines, and performed the design activities with engineering applications. In this direction, he defined product design stages as the followings first draft and construction plans; expressing these plans by means of slides, graphs, tables; making three-dimensional prototypes; performing and analyzing performance tests; and finally presenting the product. The effect of the process on academic achievement was determined with the simple machines' academic achievement test by applying before and after the procedure. The findings revealed that the process helped to increase academic achievement of the students.

Fan and Yu (2015) conducted a study about the effect of an integrative STEM approach within engineering design practices in students' learning performance. A total of 332 students (aged between 16 and 17) participated to the study for 10 weeks and were assigned to the experiemental and comparison groups. In experimental group, the students received STEM engineering module, in which they were instructed with four different instruction units based on engineering process which are designing level scales, a gear-wheeled rage finder, a cam toy, and a gear set with hands-on LEGO models and virtual computer simulation. However, in comparison groups, the students received the technology education module in which they designed based on a general design process of technology education which are selecting a design idea, testing the idea through project building, and making final design decisions. The results of the research showed that conceptual knowledge, the design project activity, and higherorder thinking skills of the students receiving STEM engineering module were significantly more improved than others receiving technology education module.

In Turkey, there are also some studies about engineering design-based science education. In the study conducted by Yıldırım and Türk (2018), female students' attitudes towards STEM and views of engineer and engineering was studied in the result of trained with STEM applications integrated to science curriculum with 87 7^{th} grade students in Muş. The students were divided in two sections randomly as experimental and comparson groups, and a science teacher instructed in both classes. Moreover, the science teacher was trained about STEM applications before the study. The teacher instructed STEM applications based on "Force and Motion" unit in experimental group for 4 weeks while existing program without any STEM application was instructed based on the same unit in comparison group. The students were instructed with the STEM activities which are wind rose, hydroelectric plants and roller coaster in experimental group. Data were collected with "STEM Attitude Scale (SAS)" to assess the students' attitudes towards STEM and "Engineering Information Form (EIF)" to assess their views of engineer and engineering through pre and post-tests. As a result of data analysis, it was revealed that STEM applications were effective in developing female students' attitudes towards STEM. In addition, it has been determined that some of the students who have the opinion that engineering is a profession for men before the applications started to have the opinion that women can also become an engineer after the applications.

In a similar study, Ercan (2014) investigated the 7th grade students' academic achievement, their decision-making skills, and their perspectives and abilities on engineering discipline in the result of participating in design-based science education practices. In the process of seven week, the students made three different modules based on design-based science education. Results of the study showed that academic achievement, perspectives for engineering discipline and engineering design process application skills (defining the problem or need, researching possible solutions, determining best solution, constructing and testing prototypes, and communication) were enhanced with design-based science education.

Moreover, the effect of engineering design-based science education was studied with teacher candidates. Yıldırım and Altun (2015) conducted a study with 83 pre-service teachers studying science education in the 3rd grade, and the lessons were processed in line with STEM education and engineering design system in the experimental group, while the lessons were processed in the normal process in the control group. As a result of this study, it was found that the change in the level of learning level of the science laboratory course increased significantly with STEM education and engineering applications, but there was no significant change in the level of learning in the classroom with normal process.

In other study, Altaş (2018) examined the effects of STEM education approach on the perceptions of classroom teacher candidates about engineering design processes and about technology and engineering. In this study, technology and engineering perceptions were analyzed in quantitative dimension of mixed method research while teacher candidates were observed in the engineering design process during six different STEM activities in qualitative dimension of the research. Results of the study concluded that engineering perceptions and skills for engineering design process steps of the teacher candidates were developed positively.

2.3. Engineering Discipline in Turkish Science Curricula

Development of the country is mostly based on education, so it is curriculum that makes the education system effective in a country. For this reason, it can be said that the curriculum is the heart of the education in a country. Questions about what textbooks and other supporting materials for learning should be like; how schools and the educational system should be organized and managed; how learners should be assessed etc. are included in the term of curriculum. As other curriculum in different subjects (Mathematics, Turkish etc.) have been progressed many times, science curriculum development and implementation have also developed for many times internationally in the history. According to Coll and Taylor (2012), curriculum developments should be needs-based and about health-related matters.

2.3.1. 2017 Turkish Science Curriculum

In 2017, a new science curriculum was published named as "2017 Turkish Science Curriculum" in Turkey (MEB, 2017). The new curriculum was a partially revised version of "2013 Turkish Science Curriculum" because of some evaluations. According to 2017 Turkish Science Curriculum, there were no extensive changes in the new curriculum in terms of learning approach and vision (MEB, 2017). In the curriculum of 2017, the students could have interdisciplinary point of view for their problems with integration of science with mathematics, technology and engineering. (Şentürk & Aydoğmuş,2017). Although there were objectives about science, technology and mathematics disciplines of STEM education in 2013 Turkish Science Curriculum, objectives about engineering discipline were not emphasized clearly. For this reason, engineering design-based activities supported the integration of engineering discipline to science education to make "Engineering(E)" part in STEM education clear (MEB, 2017). "Science and Engineering Applications" that was not included in other curricula was added to 2017 Turkish Science Curriculum as a new unit in each grade level (Figure 2.2.), and innovative and entrepreneurial thinking skills were added in the context of 21. century skills.

Engineering design-based activities as part of "Science and Engineering Applications" in each grade level were approaches for solving problems of engineers basically. Engineering design-based science education is teaching approach which includes integration of STEM disciplines to gain targeted behaviors and skills of producing solutions for engineering design problems in the daily life (Hacıoğlu, Yamak & Kavak, 2016). Students can understand interdisciplinary interactions, establish connections between engineering and science, and develop worldviews by bringing in what they learn in an experiential way with the help of engineering practices. (Şentürk & Aydoğmuş,2017).

Sınıf	No	Ünite Adı	Konu Alanı Adı	Kazanım Sayısı	Süre	
					Ders Saati	Yüzde %
5	1	Güneş, Dünya ve Ay	Dünya ve Evren	7	28	19,4
	2	Canlılar Dünyası	Canlılar ve Yaşam	2	12	8,3
	3	Kuvvetin Ölçülmesi ve Sürtünme	Fiziksel Olaylar	4	12	8,3
	4	Madde ve Değişim	Madde ve Doğası	6	26	18,1
	5	Işığın Yayılması	Fiziksel Olaylar	6	22	15,3
	6	İnsan ve Çevre	Canlılar ve Yaşam	6	16	11,1
	7	Elektrik Devre Elemanları	Fiziksel Olaylar	3	16	11,1
	8	Fen ve Mühendislik Uygulamaları	Uygulamalı Bilim	3	12	8,3
			Toplam	36	144	100
6	1	Güneş Sistemi ve Tutulmalar	Dünya ve Evren	5	14	9,7
	2	Vücudumuzdaki Sistemler	Canlılar ve Yaşam	11	24	16,7
	3	Kuvvet ve Hareket	Fiziksel Olaylar	5	14	9,7
	4	Madde ve Isı	Madde ve Doğası	13	28	19,4
	5	Ses ve Özellikleri	Fiziksel Olaylar	9	24	16,7
	6	Vücudumuzdaki Sistemler ve Sağlığı	Canlılar ve Yaşam	9	16	11,1
	7	Elektriğin İletimi	Fiziksel Olaylar	5	12	8,3
	8	Fen ve Mühendislik Uygulamaları	Uygulamalı Bilim	4	12	8,3

Figure 2.2. Unit Distribution of 5th and 6th Grade in 2017 Turkish Science Curriculum

Source: MEB, 2017, p.9

2.3.2. 2018 Turkish Science Curriculum

In 2018, a new science curriculum was published named as "2018 Turkish Science Curriculum" in Turkey (MEB, 2018). The new curriculum was a partially revised version of "2017 Turkish Science Curriculum" because of evaluations. As different from 2017 Turkish Science Curriculum, "Science, Engineering and Entrepreneurship Applications" was added as a new term instead of the term of "Science and Engineering Applications". Although, approaches and visions were the same in each subject area, this new subject area, "Science, Engineering and Entrepreneurship Applications", was not emphasized as a separate unit in each grade level because it was integrated in each grade level (Figure 2.3).

Therefore, engineering design-based activities were integrated as part of "Science, Engineering and Entrepreneurship Applications" in each grade level in 2018 Turkish Science Curriculum by revising 2017 Turkish Science Curriculum to improve students' engineering and design skills. Within the context of these regulations, beginning from 4th grade, the students were expected to make activities or projects as part of “Science, Engineering and Entrepreneurship Applications” by considering their daily life problems (MEB, 2018).

5. SINIF					
No	Ünite Adı	Konu Alanı Adı	Kazanım Sayısı	Süre	
				Ders Saati	Yüzde %
0 Fen, Mühendislik ve Girişimcilik Uygulamaları	* Fen, Mühendislik ve Girişimcilik Uygulamaları bölümündeki yönergelere göre öğrencilerden yıl içerisinde uygulamalar yapması beklenir.				
1	Güneş, Dünya ve Ay	Dünya ve Evren	7	24	16,6
2	Canlılar Dünyası	Canlılar ve Yaşam	1	12	8,3
3	Kuvvetin Ölçülmesi ve Sürtünme	Fiziksel Olaylar	5	12	8,3
4	Madde ve Değişim	Madde ve Doğası	6	26	18,1
5	Işığın Yayılması	Fiziksel Olaylar	6	22	15,3
6	İnsan ve Çevre	Canlılar ve Yaşam	8	20	13,9
7	Elektrik Devre Elemanları	Fiziksel Olaylar	3	16	11,1
	Fen, Mühendislik ve Girişimcilik Uygulamaları: Yıl Sonu Bilim Şenliği (Öğrencilerin yıl içerisinde ortaya çıkardıkları ürünü etkili bir şekilde sunmaları beklenir.)			12	8,3
		Toplam	36	144	100

6. SINIF					
No	Ünite Adı	Konu Alanı Adı	Kazanım Sayısı	Süre	
				Ders Saati	Yüzde %
0 Fen, Mühendislik ve Girişimcilik Uygulamaları	* Fen, Mühendislik ve Girişimcilik Uygulamaları bölümündeki yönergelere göre öğrencilerden yıl içerisinde uygulamalar yapması beklenir.				
1	Güneş Sistemi ve Tutulmalar	Dünya ve Evren	5	14	9,7
2	Vücudumuzdaki Sistemler	Canlılar ve Yaşam	11	24	16,7
3	Kuvvet ve Hareket	Fiziksel Olaylar	5	14	9,7
4	Madde ve Isı	Madde ve Doğası	13	28	19,4
5	Ses ve Özellikleri	Fiziksel Olaylar	9	22	15,3
6	Vücudumuzdaki Sistemler ve Sağlığı	Canlılar ve Yaşam	11	18	12,5
7	Elektriğin İletimi	Fiziksel Olaylar	5	12	8,3
	Fen, Mühendislik ve Girişimcilik Uygulamaları: Yıl Sonu Bilim Şenliği (Öğrencilerin yıl içerisinde ortaya çıkardıkları ürünü etkili bir şekilde sunmaları beklenir.)			12	8,3
		Toplam	59	144	100

Figure 2.3. *Unit Distribution of 5th and 6th Grade in 2018 Turkish Science Curriculum*

Source: MEB, 2018, pp.12-13

2.4. Attitudes Towards STEM

Burke and Mattis stated that economical growth, the stability and security of the nations, and citizens health needs the progress of knowledge, and attitudes towards STEM fields (as cited in Popa & Ciascai, 2017). Therefore, there have been growing rate in the number of employement opportunities in STEM fields in the first decay of 21st century (Faber, Unfried, Wiebe, Corn, Townsend, & Collins, 2013). These employements require knowledge in STEM fields and 21st century skills which are critical thinking, communication, colloboration, problem solving, self management etc.). Therefore, demand for these employements in STEM fields encourages to increase in the number of graduates having STEM competencies and 21st century skills (Faber et al., 2013). Accordingly, new generation students should be trained with this consciousness, and gained knowledge and skills to solve their problems that they may encounter. Nargund-Joshi and others (2013) stated that the students should integrate their knowledge and 21st century skills .to different situations in their daily lives. Thus, the students should be encouraged for educational environment which integrates different disciplines for necessary knowledge, innovation qualifications and 21st century skills. However, more students are needed to be interested in STEM careers for economic growth and one of the major goals of K-12 STEM education in U.S. is to develop students' attitudes towards STEM (Guzey, Harwell, & Moore, 2014). Moreover, students' learning and motivation to learn STEM subjects can be affected from their attitudes (Osborne, Simon & Collins, 2003; Guzey, Harwell, & Moore, 2014).

In the literature, there have been many researches about students' attitudes towards science and mathematics, less researches about their attitudes towards technology and engineering separately (Guzey, Harwell, & Moore, 2014). According to Moore and Sutman (1970), scientific attitude is "an opinion or position taken with respect to a psychological object in the field of science" and it is consisted of likes, feelings, beliefs and opinions toward science field (Krynowsky, 1988). The results of many studies presented that students' career choices are affected from their positive attitudes towards science. Like the researches on attitudes towards science, many studies also were conducted on students' attitudes towards mathematics by focusing on the relationship between their achievement and attitudes towards mathematics (as cited in Guzey, Harwell, & Moore, 2014). Moreover, the researches about students' attitudes towards technology have gained importance in the literature because of using technologies as fundamental tools in schools nowadays. However, studies about the attitudes towards engineering discipline are very limited because of becoming a new research area. Most of the studies are about the implementation of engineering instructional practices (Guzey, Harwell, & Moore, 2014). Therefore, there have been also limited studies about the effect of engineering design activities on students' attitudes towards STEM (Guzey, Moore, Harwell, & Moreno, 2016). Moreover, Blalock, Lichtenstein, Owen, Pruski, Marshall, and Toepperwein (2008) stated that there have been variety of instruments assessing students' attitudes towards STEM, but they were developed to assess attitudes towards one of the STEM disciplines. For this reason, STEM subjects are learnt through separated STEM education rather than integrated STEM education.

Researches showed that numbers of students who study post-compulsory science and mathematics decrease around the world (as cited in McDonald, 2016). The reason of this declining focuses on students' motivation towards mathematics and science because of transition from primary school to high school (McDonald, 2016). This decrease in motivation also affects students' attitudes towards STEM career choices. For example, the exam results of first 1000 students applied by ÖSYM (Öğrenci Seçme ve Yerleştirme Merkezi) between 2000 and 2014 in the numeric field showed that there is statistically decrease from 85,63% in 2000 to 38,23% in 2014 in STEM field in Turkey. Therefore, students' attitudes towards STEM disciplines can be increased with the integration of technology and engineering in K-12 curriculum. Integration of engineering in curriculum increases students' academic achievement, 21st century skills, motivation towards science learning and attitudes towards STEM (Moore et al., 2015). For this reason, engineering design-based activities support the integration of engineering discipline with science education (NAE & NRC, 2014; Ercan, 2014).

2.4.1. Studies about Attitude Towards STEM

Guzey, Harwell and Moore (2014) investigated students' (grades 4-6) attitudes towards STEM and STEM careers. A total of 662 students (57 4th graders, 332 5th graders, and 273 6th graders) voluntarily participated to the study. 203 of the students were from STEM-focused school while 459 students were from non-STEM-focused school. In non-STEM-focused schools, the students did not receive a separate engineering class, and they learnt engineering in science classes. However, the students learnt about engineering design process and engineering as a seperate engineering class, so integrated STEM education was used in STEM-focused schools. Data were collected through the survey developed by the authors to assess the students' attitudes towards STEM. The survey includes 32 items of 5-point Likert-type. The result of the study showed that STEM-focused schools significantly affect the mean score of the students' attitudes towards STEM over other students participated in non-STEM-focused schools.

In other study, Guzey, Moore, Harwell and Moreno (2016) conducted the study about the effects of engineering design-based science curriculum on 7th grade students' learning and attitudes towards STEM. Three middle school life science teachers participated in the 3-week-long summer professional development program in which they learnt about engineering design and developed a design-based unit together. The unit was prepared based on eight practices of science and engineering practices; define problems, develop and use models, plan and carry out investigations, analyze and interpret data etc. Then, 275 students of 7th grade were implemented the prepared curriculum unit by these trained teachers. Data were collected by using a content test to assess students' understanding in engineering, science and mathematics disciplines, and attitude survey to assess students' attitudes towards STEM in both before and after the engineering-based curriculum unit. The result of the study showed that there was statistically significance increase on 7th students' academic success in science concepts and attitudes towards STEM after receiving engineering-based curriculum unit.

The similar study by Mahoney (2010) investigated the effect of high school STEM-based programs on students' attitudes towards STEM over a conventional college preparatory school; and the students' attitudes towards STEM for the independent variable of gender. Participants of the study were 144 10th and 11th grade students. Some of the students were from a high school consisting of STEM-based program while other students were from the other high school consisting of conventional college preparatory program. In STEM-based program schools, the students received specific focus and dedication toward STEM. Data were collected by the instrument to measure the students' attitudes towards STEM. The instrument included total of 96 items in science, technology, engineering and mathematics disciplines for principal components of interest, ability and value. The result of the study indicated that male students showed significantly more positive attitude towards STEM than the female students for the independent variable of gender. However, the high school students in the STEM-based high school did not show significant positive attitude towards STEM comparing to the students of conventional college preparatory school.

Özcan and Koca (2019) investigated the effect of a teaching module based on STEM approach on 7th grade students' academic achievement and their attitudes towards STEM. A total of 33 7th students participated to the study for 2017-2018 school year. At teaching module based on STEM education approach about the subject of "Pressure" was applied in experimental group (n=20) while the approach about the same subject as stated in the curriculum was applied in comparison group (n=13). Teaching module which was used in experiemental group was prepared based on 5E model while the lesson plans which were implemented in comparison group were prepared based on the research-question based teaching structure as stated in the curriculum. The process of the study was 12 lesson hours. Data were collected through an academic achievement test, semi-structured interviews, an attitude scale for STEM, and the students' diaries. Attitude towards STEM scale includes 37 items, 5-point Likert type scale. The result of the study showed that experimental group taught with STEM education approach showed increased academic achievement and more positive attitude towards STEM over other students participated in comparison group.

In other study, Bekir and Selvi (2017) conducted the study about the effect of a STEM applications and master learning on 7th grade students' academic achievement, inquiry learning skills perceptions, motivations, their attitude towards STEM applications and permanence of information of the secondary school students. 78 7^{th} grade students in 3 different class participated to the study. The students in first class were taught with STEM applications, the students in second class were taught with STEM applications and master learning, and other students in third class were taught with the lessons as stated in the curriculum. The first and second classes were experimental group (n=56) while other students in third class were comparison group (n=22). The process of the study was 8 weeks. Data were collected through achievement tests which are "Academic Achievement Test I (AAT I)" and "Academic Achievement Test II (AAT II)", "Scale of Inquiry Learning Skills Perception towards Science (SOILSPTS)", "Motivation Scale towards Science (MSTS)" and "STEM Attitude Scale (SAS)". STEM Attitude Scale (SAS) wad adapted into Turkish version by Yıldırım and Selvi (2015) and it includes 37 items, 5-point Likert type scale. The result of the study showed that experimental group taught with STEM education approach showed developed motivation for academic achievement and motivation, positive permanence of the learned information. However, participants did not show inquiry learning skills perceptions for STEM attitude and science after participating STEM applications and mastery learning.

In addition to these studies about the attitudes towards STEM, the results of some studies about attitudes towards STEM were also explained in the "Studies about STEM Education" and "Research on Engineering Design-Based Science Education" parts above. Some of these studies conducted by Guzey, Moore, Harwell, and Moreno (2016); Yamak and others (2014); Yasak (2017); Baran, Canbazoğlu-Bilici and Mesutoğlu (2015); and Türk (2018) examined change in attitudes towards STEM or science.

CHAPTER 3

METHODOLOGY

In methodology chapter, model of the research; research group (participants) of the study; and instruments for data collection; and administration parts are presented.

3.1. Design of the Study

The purpose of the present study is to study the effects of engineering design-based instruction on 7th grade students' nature of engineering views and attitudes towards STEM. Therefore, quantitative research was operated by supporting with qualitative data to attain the purpose of the study. Quantitative research uses specific statistical techniques to explain an issue or phenomenon by numerical data. It answers questions like what, where, when, how many, and how (Apuke, 2017). According to Williams (2011), quantitative research covers a statement of a problem, hypothesis and research questions, related literature review, and quantitative analyses of data.

In the present study, quantitative research was operated to examine students' nature of engineering views and attitudes towards STEM. Students' nature of engineering views with an open-ended scale which is "Views for Nature of Engineering - Elementary School Version (VNOE-E)" (Yesilyurt, Deniz & Kaya, 2019); and students' attitudes towards STEM with a 5-point Likert-type questionnaire which is "STEM Attitude Scale: Middle School Version (M-STEM)" (Yıldırım, 2015) were analyzed. Collected data from these 2 different scales were analyzed with IBM SPSS Statistics 24.0. However, in qualitative researches, the main purpose is to collect detailed data about the studied topic. Therefore, students' nature of engineering views was also analyzed as qualitatively to support quantitative results of the study.

In this study, engineering design-based activities which were integrated into "Force and Energy" unit covered in 2018 Science Curriculum were implemented in 7th grade science classroom. Within the context of this unit, “Tower Construction” and “Parachute Construction” activities were prepared. To evaluate the effects of these activities in quantitative part of the study, the static group pretest-posttest design was used because the participants were not randomly assigned into the groups (Fraenkel & Wallen, 2006). However, experimental (E) and comparison (C) groups were randomly assigned among already formed two intact sections of 7th grades. Independent variable of the design of the study is engineering design-based activities, while dependent variables are students’ nature of engineering views and attitudes towards STEM. Design of the study is shown in Table 3.1. below.

Table 3.1. *Symbolic Notation of the Randomized Pretest- Posttest Comparison Group Design*

Group	*Randomization*	*Pre-Test*	*Treatment*	*Post-Test*
E	R	O_1, O_2	EDBI	O_1, O_2
C	R	O_1, O_2	CBI	O_1, O_2

In the Table 3.1 above, experimental group is represented with “E”, comparison group is represented with “C”, and these groups were randomly assigned which is stated with “R” at the beginning of study. To control the subject characteristics threat to internal validity of the study, random assignment is influential technique (Fraenkel, Wallen, & Hyun, 2012). In this study, the effects of engineering design-based instruction on students’ nature of engineering views and attitudes toward STEM were investigated, so engineering design-based instruction (EDBI) was operated in the experimental group (E) while curriculum-based instruction (CBI) based on the objectives in 2018 Science Curriculum was operated in the comparison group (C). To evaluate the effects of engineering design-based activities, 2 different instruments which are “Views for Nature of Engineering-Elementary School Version (VNOE-E)” stated with “O_1"; and “STEM Attitude Scale: Middle School Version (M-STEM)” stated with “O_2" were used as pre and post-tests.

3.2. Research Group (Participants) of the Study

In the present study, all 7th grade students in public schools in Ankara were identified as the target population of the study while all 7th grade students in a public school of Çankaya district of the city was chosen as accessible population. Accordingly, convenience sampling was preferred by the researcher. Convenience sampling is a technique for preferring a group of individuals who are available for the study and one of the most common sampling techniques because of providing easy accessibility (Fraenkel, Wallen, & Hyun, 2012). Therefore, a public elementary school in Çankaya district of Ankara was selected conveniently by the researcher in 2018-2019 school year. This public school was available for the aim of the study, and school administration offered unlimited research opportunities like science lesson hours for the application of the study. In addition, it was nearby middle school for the researcher, so loss of money, effort and labor force were minimized with convenience sampling. After necessary consultations about the study with the school administration and science teachers of 7th grades, the compulsory permission was received from Governor's Office of Ankara and Provincial Directorate of National Education (Appendix-A).

In this selected school, there were 3 different sections of 7th grade. The fact that there were no any criteria while forming these sections was stated by the school administration during the consultation. In other words, all these 3 different sections had heterogeneous structure in terms of academic achievement and socio-economic status. Number of the students in these sections was between 17 and 24. Two different 7th grade sections (7B and 7C) were selected randomly by the researcher. The students in one section were comparison group of the study while other students in other section were experimental group of the study. The number of the students in these selected sections in terms of section size and genders is stated in Table 3.2. below.

Table 3.2. *Distribution of the Students in Experimental and Comparison Groups*

	Experimental Group (E)		*Comparison Group (C)*		*Total*
	Male	*Female*	*Male*	*Female*	
Frequency (f)	9	15	11	6	41
Total	24		17		

In comparison group, curriculum-based instruction based on the objectives about the unit of "Force and Energy" on 2018 science curriculum was administered by the science teacher while in experimental group, engineering design-based instruction which was developed by considering objectives about the unit of "Force and Energy" on 2018 science curriculum was administered by the researcher.

3.3. Data Collection

In this part, instruments for data collection and administration of the procedure are presented.

3.3.1. Description of Instruments

In this study, quantitative research was operated, so instruments for data collection were classified as quantitative or qualitative data scales. Two different instruments were used in the study. Comprehensive information about the instruments is explained in Table 3.3. below.

Table 3.3. *List of Instruments*

Instrument	*Sub-dimensions*	*Number of Items*
VNOE-E	-	11
M-STEM	Mathematics	8
	Science	9
	Engineering	9
	21st Century Skills	11

3.3.1.1. Views for Nature of Engineering -Elementary School Version (VNOE-E)

Views for Nature of Engineering - Elementary School Version (VNOE-E) was used as both quantitative and qualitative data scale of the study. This scale was developed by Yesilyurt, Deniz and Kaya (2019) by modifying the Views of Nature of Science Questionnaire Version E (VNOS-E) (Lederman & Ko, 2004) and adding Draw-an-Engineer-Test (DAET) (Knight & Cunningham, 2004). The researcher adapted this scale into Turkish language named as "Mühendisliğin Doğasına Yönelik Görüşler; İlköğretim Versiyonu (MDYG)" (Appendix-B). The questionnaire is open-ended scale, so answers were evaluated depending on the rubric which is "Descriptions of Nature of Engineering (NOE) Aspects" (Appendix-C) developed by Deniz et al. (2017) in quantitative part of the research.

Yeşilyurt et al. (2019) developed original form of the questionnaire by modifying "Views of Nature od Science Questionnaire Version E (VNOS-E)" and implemented to a total of 6 elementary students (grades 3-5) to assess elementary students' nature of engineering (NOE) views with an engineering design experience. Students were administered the VNOE-E both at the beginning and at the end of the treatment. In data analysis, responses were analyzed based on the NOE framework describing each NOE aspects developed by the authors (Deniz, Yeşilyurt, Kaya & Trabia, 2017). The NOE framework was developed by adapting NOS research framework to assess NOE views of elementary teachers in their previous study (Deniz, Yeşilyurt, Kaya & Trabia, 2017). They pointed out that similarity between NOS and NOE aspects like tentativeness, subjectivity, socially and culturally embeddedness etc. except engineering design process (EDP). 6 participants' written responses in the VNOE-E were collectively classified by three authors according to NOE aspects, and their responses for each NOE aspect were also individually analyzed by the authors by assigning a score according to the rubric developed in this study (Deniz et al., 2017). As a result, they achieved more than 90 percent of inter-rater reliability for the questionnaire.

In the present study, Turkish version of VNOE-E was used to assess 7th grade students' nature of engineering views. This elementary version of the questionnaire covers 11 questions in terms of 7 different aspects which are engineering design process, tentativeness, demarcation criteria, subjectivity, social and cultural embeddedness, social aspects of engineering, and creativity. Questions and related NOE aspects are given in Table 3.4. below.

Table 3.4. *VNOE-E Questions and Related NOE Aspects*

Question number	*The NOE aspects question refers to*
1	General idea about engineering
2	Demarcation aspect
3	General idea about engineering
4	Demarcation aspect
5	Demarcation aspect
6	Engineering design process
7	Tentativeness
8	Creativity
9	Subjectivity
10	Social and cultural aspect
11	Social aspects of engineering

The researcher made a change in the 9th question in VNOE-E (TV commercials show that there is a variety of soda can crushers available in the market. Can there be a best soda can crusher?) by getting necessary permissions from the authors of the original form of the questionnaire (VNOE-E) while adapting the questionnaire into Turkish because a soda can crusher is not familiar for students in Turkey. Then, the clarity and comprehensibility of the adapted version in Turkish which is "Views for Nature of Engineering-Elementary School Version (VNOE-E)" was affirmed by the researcher's advisor who is a professor of science education, a science teacher and a researcher in STEM education to provide content-related validity, and the questionnaire was found to be appropriate for the students' grade level. Moreover, reliability of the VNOE-E was supplied depending on scoring agreement with another researcher who is a master student on science education and studies on STEM education according to the rubric which is "Descriptions of Nature of Engineering (NOE) Aspects" (Appendix-C) prepared by Deniz et al. (2017). The result showed that 89 percent inter-rater reliability was achieved for reliability of the instrument as shown in Table 3.5.

Table 3.5. *Intraclass Correlation Coefficient for VNOE-E*

	Intraclass Correlation
Single Measures	.80
Average Measures	.89

3.3.1.2. STEM Attitude Scale: Middle School Version (M-STEM)

In quantitative part of the study, students' attitudes towards STEM were evaluated by using STEM Attitude Scale: Middle School Version (M-STEM)". This attitude scale was originally developed by Faber, Unfried, Wiebe, Corn, Townsend and Collins (2013) named as "STEM Attitude Scale". Faber et al. (2013) developed this scale by implementing to 9081 participants in 2012-2013. It covers 37 items in terms of 4 different sub-dimensions which are mathematics, science, engineering and 21st century skills. Cronbach Alpha value of the scale was found to be 0.83 and Cronbach Alpha values of sub-dimensions were 0.83 and above (Faber et al., 2013).

Yıldırım and Selvi (2015) adapted "STEM Attitude Scale" into Turkish language named as "Ortaokul Öğrencilerinin STEM'e (M-STEM) Karşı Tutumu" (Appendix-D). The questionnaire is 5-point Likert-type scale, so answer options are organized as "5= Certainly Agree", "4= Agree", "3= Undecided", "2= Disagree", and "1= Certainly Disagree". Authors adapted this scale with 37 items in terms of 4 different sub-dimensions like in the original form of the scale. Explaratory factor analysis was applied to investigate the structural validity of the scale, and the results determined factors which are mathematics, science, engineering, technology and 21st century skills as the original scale. Then, confirmatory factory analysis to test the structure with theoretical basis was applied, and the results investigated that the scale featured a good level of fit with the fit values (x2/df = 4.72; RMSEA = 0.063, SRMR = 0.053, CFI = 0.96, GFI = 0.87, AGFI = 0.85, NFI = 0.95, IFI = 0.95). Moreover, they calculated Cronbach Alpha value of the overall scale as 0.94. In addition, Cronbach Alpha values of the sub-dimensions are 0.89 for mathematics and 21st century skills; and 0.86 for science and engineering as shown in Table 3.6. below.

Table 3.6. *Cronbach Alpha Values of "STEM Attitude Scale: Middle School Version (M-STEM)"*

	Number of Items	*Original Form (Faber et al., 2013)*	*Turkish Form (Yıldırım & Selvi, 2015)*	*In the Present Study*
Overall Scale	37	0.83 and above	0.94	0.95
Mathematics	8	0.83 and above	0.89	0.91
Science	9	0.83 and above	0.86	0.91
Engineering	9	0.83 and above	0.86	0.82
21st Century Skills	11	0.83 and above	0.89	0.91

In this study, Cronbach Alpha value of the overall scale was calculated as 0.94 for the scale. Cronbach Alpha values of the sub-dimensions were calculated as 0.91 for mathematics, science and 21st century skills; 0.82 for engineering as shown in Table 3.3. above. These values showed that this scale has high level of reliability and can be used for the study (Field, 2009).

3.3.2. Treatment

In this study, quantitative method research was operated to evaluate students' nature of engineering views and attitudes towards STEM.

Two different 7th grade classes in which while the students were comparison group in one class, other ones were experimental group were studied for 5 weeks (16 lesson hours). Two different instruments which are VNOE-E (Appendix-B), and M-STEM (Appendix-D) were administered in both classes at the beginning and at the end of the instructions as pre and posttests. In comparison group, curriculum-based instruction (CBI) was applied by the science teacher on “Force and Energy” unit, while in experimental group, engineering design-based instruction (EDBI) was applied by the researcher on the same unit. Before the implementation process, the researcher had several meetings with the science teacher, and gave information about the process of the treatment. Since the teacher had no experience of implementing engineering design-based instruction and engineering design process in classroom environment, she did not prefer to implement engineering design-based instruction to experimental group of the study. Therefore, CBI was implemented by the science teacher to the experimental group, and EDBI was applied by the researcher who had prior knowledge about engineering design process before the treatment.

For 3 weeks (12 lesson hours) which was between implementation of pre and post-test of instruments, curriculum-based instruction (CBI) on “Force, Work and Energy Relation” and “Energy Conversion” topics of “Force and Energy” unit by considering related objectives for the topic in 2018 Turkish Science Curriculum was applied to the comparison group. However, in experimental group, nature of engineering and engineering design process (Appendix-E) was presented by the researcher and a mechanical engineer, and engineering design-based instruction (EDBI) was administered by the researcher according to two different lesson plans. “Lesson Plan for Tower Construction” (Appendix-G) on the topic of “Force, Work and Energy Relation”; and “Lesson Plan for Parachute Construction” (Appendix-I) on the topic of “Energy Conversion” were prepared by the researcher. In these lesson plans, firstly, the instructor tries to make connections between prior and present knowledge by increasing the students’ curiosity towards to the topic; then, the students actively explore their environment, moved materials, define and improve concepts by questioning and discussion. After that, the students verbalize their conceptual understanding and present new skills or behaviors. Lastly, the students' understanding of concepts and development in their skills are evaluated.

These two lesson plans were developed by the researcher based on the objectives for the topic in 2018 Turkish Science Curriculum, and some activities were embedded in these lesson plans as shown in Table 3.7. below.

Table 3.7. *The details of the lesson plans used in EDBI*

Topics and Lesson Plans	*Duration*	*Objectives*	*Science Concepts*	*Activities*
Force, Work and Energy Relation (Lesson Plan for Tower Construction)	6 lesson hours	F.7.3.2.1. Explain the kinetic and potential energy by linking with energy and work concepts F.7.3.2.2. Design a 3D project related to a problem about the relation between kinetic and potential energy F.7.3.2.3. Explain nature of engineering aspects	• Force • Work • Energy • Kinetic Energy • Potential Energy • Elastic and Gravitational Potential Energy	• Presentation about Tower Construction • Watching Video on Kinetic and Potential Energy • Simulation about Kinetic and Potential Energy • Daily Life Examples for Work, and Kinetic and Potential Energy • Activity Sheet of Tower Construction (Appendix-I) • Conceptual Questions
Energy Conversion (Lesson Plan for Parachute Construction)	4 lesson hours	F.7.3.3.1. Explain conservation of energy by considering conversion of kinetic and potential energy with each other F.7.3.3.2. Explain the effect of friction force on kinetic energy with examples F.7.3.3.3. Design a 3D project related to a problem about conversion of kinetic and potential energy F.7.3.3.4. Explain nature of engineering aspects	• Kinetic Energy • Potential Energy • Conversion of Kinetic and Potential Energy • Friction Force (Air and Water Resistance)	• Presentation about Parachute Construction • Watching Video on Conversion of Kinetic and Potential Energy • Simulation about Conversion of Kinetic and Potential Energy • Daily Life Examples for Conversion Kinetic and Potential Energy • Activity Sheet of Parachute Construction (Appendix-K) • Conceptual Questions

As shown in Table 3.7., engineering design-based activities (Tower Construction and Parachute Construction) which were preaped based on engineering design process (EDP) were applied within these lesson plans. In these activities, the students were expected to solve a daily life problem in terms of engineering design process steps. As explained before, there are various types of design processes sharing similar expectations (the definition of the problem, revealing the possible solutions, analyzing, testing and evaluating the solutions and renewing the solution if necessary) (Wendell et al., 2010; Deniz et al., 2017). However, different version of the design process developed by Wendell and others (2010) was used in the present study. Last two steps of that design process were combined and formed as “building and testing prototype”. Therefore, engineering design process steps were finding a problem or need, researching possible solutions, choosing the best solution, and building and testing the prototype in the present study. During constructing these projects, activity sheets which are “Activity Sheet of Tower Construction” (Appendix-H) and “Activity Sheet of Parachute Construction” (Appendix-J) prepared by the researcher were distributed to the students to follow nature of engineering (NOE) aspects (empirical basis, demarcation criteria, tentativeness, subjectivity, social aspects of engineering, creativity, social and cultural embeddedness, and engineering design process) easily.

These engineering design-based activities were adapted from the activities which are “What is Engineering? Tower Power” and “A Long Way Down: Designing Parachutes” in Engineering is Elementary website by the researcher. These adapted activities were selected and analyzed by the researcher based on the “STEM Analysis Criteria” rubric (Aydın, 2019) (Appendix- F). According to Aydın (2019), STEM activities should be suitable for STEM approach by considering some criteria shown in Appendix-F. According to STEM analysis criteria, firstly, the activity should include a daily life problem, and also the lesson should start with this problem. In both engineering design-based activities (“Activity Sheet of Tower Construction” (Appendix-H) and “Activity Sheet of Parachute Construction” (Appendix-J), the problems were given in two different scenarios. Then, the students were encouraged to find the problem by asking a question like “What is the problem in the scenario?” in “finding a problem or need” step of EDP. Secondly, the activity should include an integration of one or more than one disciplines of STEM. In the lesson plans, engineering design-based activities were prepared based on engineering design process (EDP). The students followed steps of EDP respectively (Table 3.8.).

Table 3.8. *Activity Sheets*

Step	
Finding a problem or need	The students identified the problem or need, and criteria and constraints for the final product or system by asking questions
Researching possible solutions	The students searched for existing solutions, and brainstorm for alternative solutions by considering criteria and constraints
Choosing the best solution	The students analyzed and evaluated many solutions they propose within the framework of design criteria and constraints and chose the solution that best meets the criteria and constraints
Building and testing the prototype	Individuals design their prototype by putting into practice of knowledge in the theory they learnt and by considering the limitations and success criteria. Then, protypes were tested, and if there were deficiencies in the prototype, the students were encouraged to redesign them for the next lesson.

Therefore, science (kinetic and potential energy concepts) and engineering (application of engineering design process steps) disciplines of STEM could be provided with engineering design-based activities in the present study. Thirdly, the activitiy should be student-centered. In the present study, the activities gave an opportunity to the students about making their own searches in “researching possible solutions” step, enabled the students to present scientific questions when they made their own designs (“How should the tower be? Long or short?” or “How should the air resistanbe be? Much or little?”). The students chose their materials by making discussions with their group members, and they decided their design of prototypes freely according to constrains and criteria. The researcher only guided students during the process by asking questions, so activites were student-centered. In these activities project-based learning was used in which students were expected to find the problems and designed their prototypes by making discussion with their group members and presented prototypes verbally. The activity should provide an opportunity to the students to work in small groups and group communication. During engineering design process steps, the students worked in small groups (4-5 students) by acting as an engineer and discussed criteria and constraints, chose materials and designed their prototypes together. After designing, the students tested their prototypes based on the rubric as stated in the appendices (Appendix-H and Appendix-J). Then, if there were deficiencies in the prototype, the students were encouraged to redesign them for the next lesson. In addition, in the activity sheet, there were some questions about what and why they made changes in their prototype. Lastly, in activity sheets, the rubric for evaluation, the criteria and constraints were presented to the students at the beginning of the designs.

Revisions and evaluations about lesson plans and engineering design-based activities were carried out based on feedbacks of the advisor of the researcher who is a professor of science education, another researcher who is a master student on science education and studies on STEM education and the science teacher.

3.3.2.1. Engineering Design-Based Instruction (EDBI)

In experimental group (7/C), engineering design-based instruction (EDBI) was administered by the researcher based on two different lesson plans, which were explained before in Table 3.7., for 3 weeks (10 lesson hours) as presented in detail in Table 3.9. below.

After administration of two different instruments (VNOE-E and M-STEM) as pre-tests, in experimental group in the first two lesson hours of the second week, the researcher and a mechanical engineer explained nature of engineering (NOE) aspects namely, demarcation criteria (What is engineering? What makes engineering different from other disciplines?), tentativeness, subjectivity, social aspects of engineering, creativity, social and cultural embeddedness, empirical basis, and engineering design process steps with the engineer’s experiences and studies. At the beginning of the lesson, the researcher asked some questions to the students like “Do you want to become an engineer when you grow up?", "What is engineering?", "What are the engineering products in your daily life?", "Which type of engineering do you know?" to increase the students' attention to the lesson. Then, the mechanical engineer presented NOE aspects, engineering design process steps, and his projects. Therefore, discussion-based lesson was made among the researcher, the engineer and the students by using visual supported presentation (Appendix-E) on the smartboard.

In other two lesson hours of the week, the same topic which is "Force, Work and Energy Relation" was started by the researcher based on engineering design-based instruction (EDBI) in experimental group. The researcher administered the lesson according to the lesson plan which is "Lesson Plan for Tower Construction" (Appendix-G). In two lesson hours, the students' prior knowledge about force, mass and weight concepts was obtained by questioning; then, the students were initiated for the topic of force, work and energy relation by a video and a simulation about kinetic and potential energy. After engagement to the lesson, the students made necessary explanations about work, kinetic and potential energy, and the types of potential energy (elastic and gravitational potential energy concepts) and gave daily life examples for them under the guidance of the researcher by questioning method.

In the third week, an engineering design-based activity which is "Tower Construction" was started, and this activity was prepared based on engineering design process (EDP). "Activity Sheet of Tower Construction" (Appendix-H) which is covered in the lesson plan was distributed to the students to follow engineering design process (EDP) steps easily. During this activity, the students were expected to study in group (4-5 students), and also the students acted as an engineer during activities. Therefore, the name cards were distributed to the students like "Engineeer XX". In the first two lesson hours of the week, the students followed first three steps which are "Finding a problem or need", "Researching possible solutions", "Choosing the best solution" in the engineering design-based activity. Firstly, the students read the scenario, and integrated kinetic and potential energy concepts to the scenario. Then, the students recalled engineering design process steps which were explained in previous week.

Next, in the first step of EDP, the students asked to identify the problem or need in the scenario started. In next step, "researching possible solutions", the students searched for existing solutions, and brainstorm for alternative solutions by considering criteria and constraints. The students integrated their knowledge about potential and kinetic energy and solution for the identified problem in previous step. They decided that if the tower should be long or short or not by considering these scientific concepts. In addition, the constraints and criteria were given to the students for their tower construction (cost, materials, time etc.). Then, the students decided their materials with their group members by discussion in the light of the constraints and criteria. In the third step, the students analyzed and evaluated many solutions and chose the solution that best meets the criteria and constraints. Then, they drew their design in the activity sheets. In next two lessons of the week, last step which is "Building and testing the prototype" of EDP was covered, and four evaluation questions (7th, 8th, 9th and 10th questions) in the activity sheet were answered by the students. In the first lesson, each group built their own towers decided on "Choosing the best solution" step of EDP in previous lesson. In the next lesson, each group tested their prototypes based on evaluation rubric (Appendix-L) and answered last four conceptual questions (7^{th}, 8^{th}, 9^{th} and 10^{th} questions) in the activity sheet. These questions were about design and redesigning the prototypes.

In the fourth week, next topic which is "Energy Conversion" of "Force and Energy" unit was started in each class. In experimental group, the researcher administered an engineering design-based activity like previous week. The researcher administered "Lesson Plan for Parachute Construction" (Appendix-I). In first two lesson of the week, the students' prior knowledge about work, energy, and kinetic and potential energy concepts was obtained; then, the students were initiated for the topic by a video and the simulation about kinetic and potential energy used in previous activity. After engagement to the lesson, the students made necessary explanations about conversion of kinetic and potential energy with each other and gave daily life examples for them by using questioning method by the researcher. Then, "Activity Sheet of Parachute

Construction" (Appendix-J) which is covered in the lesson plan was distributed to the students to follow EDP steps easily. Like in previous activity, the same procedures were followed; the students studied in group (4-5 students) and acted as an engineer. In the first two lesson hours of the week, first three steps ("Finding a problem or need", "Researching possible solutions", "Choosing the best solution") of EDP depending on "Parachute Construction" activity was followed by the students. Firstly, the students read the scenario, and tried to find the related kinetic and potential energy concepts and conversion of them with each other in the scenario. Then, the students recalled engineering design process steps which were explained in previous weeks. Next, the students started with "finding a problem or need" of EDP and identified the problem or need in the scenario. In next step, "researching possible solutions", the students searched for existing solutions, and brainstorm for alternative solutions by considering criteria and constraints. The students integrated their knowledge about energy conversion and solution for the identified problem in previous step. They decided that if the parachute should have much or little air resistance or not by considering these scientific concepts. In addition, the constraints and criteria were given to the students for their parachute construction (cost, materials, time etc.). Then, the students decided their materials with their group members by discussion in the light of the constraints and criteria. In the third step, the students analyzed and evaluated many solutions and chose the solution that best meets the criteria and constraints. Then, they drew their design in the activity sheets. In next two lessons of the week, last step which is "Building and testing the prototype" of EDP covered, and four evaluation questions (7th, 8th, 9th and 10th questions) in the activity sheet were answered by the students. In the first lesson, each group built their parachute decided in "Choosing the best solution" step of EDP in previous lesson. In the next lesson, each group tested their products based on the evaluation rubric (Appendix-M) by throwing them from the window of the class and answered last four conceptual questions (7^{th}, 8^{th}, 9^{th} and 10^{th} questions) in the activity sheet. These questions were about design and redesigning the prototypes.

Table 3.9. *Administration Schedule for "Force and Energy" Unit of 7th Grade Students*

Week	***Topic***	***Date/Hour***	***Group***	***Administrator***	***Administration***	***Used Instruments***
1st week	Pre-Tests	05.12.2018 (2 hours)	7/C 7/B	Researcher	Application of 2 different instruments to evaluate students' nature of engineering views and attitudes towards STEM as pretests	• Views for Nature of Engineering; Elementary School Version (VNOE-E) (Appendix-D) • STEM Attitude Scale: Secondary School Version (S-STEM) (Appendix-F)
2nd week	F.7.3.2. Force, Work and Energy Relation	11.12.2018 (2 hours)	7/C	Researcher	Presentation about nature of engineering (NOE) and engineering design process (EDP) by the researcher and a mechanical engineer	• Nature of Engineering (Appendix-G) • Observation Report for Teaching Procedure (Appendix-L)
			7/B	Science Teacher	Administration of the terms of force, work and energy related to objectives about the topic of "Force, Work and Energy Relation" on 2018 science curriculum	• Observation Report for Teaching Procedure (Appendix-L)

Table 3.9. *Administration Schedule for "Force and Energy" Unit of 7th Grade Students (cont'd)*

2nd week	F.7.3.2. Force, Work and Energy Relation	12.12.2018 (2 hours)	7/C	Researcher	Administration of science lecture related to objectives about the topic of "Force, Work and Energy Relation" on science curriculum (Prior Knowledge, Video and Simulation, Explanation)	• Lesson Plan for "Tower Construction" (Appendix-H) • Observation Report for Teaching Procedure (Appendix-L)
			7/B	Science Teacher	Administration of the term of kinetic energy related to objectives about the topic of "Force, Work and Energy Relation" on science curriculum	• Observation Report for Teaching Procedure (Appendix-L)
3rd week	F.7.3.2. Force, Work and Energy Relation	18.12.2018 (2 hours)	7/C	Researcher	Administration of "A. Finding a problem or need", "B. Researching possible solutions", and "C. Choosing the best solution" steps of EDP	• Lesson Plan for "Tower Construction" (Appendix-H) • Activity Sheet of "Tower Construction" (Appendix-I) • Observation Report for Teaching Procedure (Appendix-L)

Table 3.9. *Administration Schedule for "Force and Energy" Unit of 7th Grade Students (cont'd)*

			7/B	Science Teacher	Administration of potential energy related to objectives about the topic of "Force, Work and Energy Relation" on science curriculum	• Observation Report for Teaching Procedure (Appendix-L)
3rd week	F.7.3.2. Force, Work and Energy Relation	19.12.2018 (2 hours)	7/C	Researcher	Administration of "D. Building and testing the prototype" step of EDP and evaluation questions (7th, 8th, 9th and 10th questions) in the activity sheet	• Lesson Plan for "Tower Construction" (Appendix-H) • Activity Sheet of "Tower Construction" (Appendix-I) • Observation Report for Teaching Procedure (Appendix-L) • Students' final products about "Tower Construction" (Appendix-M)
			7/B	Science Teacher	Administration of summary about the topic of "Force, Work and Energy Relation" and "Unit Assessment Questions" on the 7th grade science textbook	• Observation Report for Teaching Procedure (Appendix-L)

Table 3.9. *Administration Schedule for "Force and Energy" Unit of 7th Grade Students (cont'd)*

4th week	F.7.3.3. Energy Conversion	25.12.2018 (2 hours)	7/C	Researcher	Administration of science lecture related to objectives about the topic of "Energy Conversion" on science curriculum (Prior Knowledge, Video and Simulation, Explanation) and "A. Finding a problem or need", "B. Researching possible solutions", and "C. Choosing the best solution" steps of EDP	• Lesson Plan for "Parachute Construction" (Appendix-J) • Activity Sheet of "Parachute Construction" (Appendix-K) • Observation Report for Teaching Procedure (Appendix-L)
			7/B	Science Teacher	Administration of conversion of kinetic and potential energy related to objectives about the topic of "Energy Conversion" on science curriculum	• Observation Report for Teaching Procedure (Appendix-L)

Table 3.9. *Administration Schedule for "Force and Energy" Unit of 7th Grade Students (cont'd)*

4th week	F.7.3.3. Energy Conversion	26.12.2018 (2 hours)	7/C	Researcher	Administration of "D. Building and testing the prototype" step of EDP and evaluation questions (7th, 8th, 9th and 10th questions) in the activity sheet	• Lesson Plan for "Parachute Construction" (Appendix-J) • Activity Sheet of "Parachute Construction" (Appendix-K) • Observation Report for Teaching Procedure (Appendix-L) • Students' final products about "Parachute Construction" (Appendix-N)
			7/B	Science Teacher	Administration of summary about conversion of kinetic and potential energy related to objectives about the topic of "Energy Conversion" on science curriculum	• Observation Report for Teaching Procedure (Appendix-L)
5th week	Post-Tests	02.01.2018 (2 hours)	7/C 7/B	Researcher	Application of 2 different instruments to evaluate students' nature of engineering views and attitudes towards STEM	• Views for Nature of Engineering; Elementary School Version (VNOE-E) (Appendix-D) • STEM Attitude Scale: Secondary School Version (S-STEM) (Appendix-F)

3.3.2.2. Curriculum-Based Instruction (CBI)

In comparison group (7/B), curriculum-based instruction (CBI) was administered by the science teacher based on the objectives in 2018 Turkish Science Curriculum for 3 weeks (12 lesson hours) as presented in detail in Table 3.9. above. Any activities related to EDBI were not performed in CBI group, so the teacher mainly used lecturing and questioning during the lessons.

After administration of two different instruments (VNOE-E and M-STEM) as pre-tests, in comparison group in the first two lesson hours of the second week CBI was started by the science teacher on “Force, Work and Energy Relation” topic by considering related objectives in 2018 Turkish Science Curriculum. Force, work and energy concepts, and their units were explained by the science teacher depending on 7th Grade Science Textbook (MEB, 2018). The students and teacher gave some examples for these concepts from their daily life. For example; the teacher explained that there is a work while pushing a table, but there is no any work while walking when moving a bag. In other two lesson hours of the week, CBI was maintained about kinetic energy. Kinetic energy concept was explained by the science teacher depending on 7th Grade Science Textbook (MEB, 2018). The students and teacher gave some examples for the concept from their daily life. While explaining these concepts, the simulation about kinetic and potential energy, which was also used in EDBI group, was operated by the teacher.

In the third week, the next science concept which is potential energy was instructed based on curriculum-based instruction (CBI) by the teacher. Potential energy concept was explained depending on 7th Grade Science Textbook (MEB, 2018), and the simulation, which was used in previous lesson, was also used in the lesson. The students and teacher gave some examples for the term from their daily life. In next two lesson hours of the week, brief repetition about work, energy, potential and kinetic energy science concepts depending on the CBI was made by the science teacher by considering related objectives for the topic in 2018 Turkish Science Curriculum.

Moreover, questions related to the topic in the textbook were answered by the students to reinforce the science concepts.

In the fourth week, the next topic which is "Energy Conversion" was started based on CBI by the science teacher by considering related objectives in 2018 Turkish Science Curriculum. Conversion of kinetic energy and potential energy with each other were explained by the science teacher depending on 7^{th} Grade Science Textbook (MEB, 2018). While explaining these concepts, the simulation about kinetic and potential energy, which was also used in previous weeks, was operated by the teacher because it covers also conversion of energy types with each other. The students and teacher gave some examples for these conversions from their daily life. In next two lessons of the week, brief repetition about "Energy Conservation" topic was made by the science teacher. Moreover, questions related to the topic in the textbook were answered by the students to reinforce the conversion of kinetic and potential energy with each other.

3.4. Treatment Fidelity and Verification

Treatment fidelity is the verification of the comparison group was instructed with curriculum-based instruction (CBI) and experimental group was instructed with engineering design-based instruction (EDBI). CBI and EDBI were defined clearly to ensure treatment fidelity. Literature review on engineering design-based instruction provides framework for the development of lesson plans. Advisor of the study who is a professor of science education guided and reviewed instructional materials.

Treatment verification of the present study was ensured by "Observation Report for Teaching Procedure" (Appendix-K) during instructions in each week in both classes by science teacher and the researcher. The observation report was developed by the researcher in the present study. The report includes items about how the lesson was started by the instructor, the strategies to emphasize the purpose and content of the lesson (direct explanation, exploration of students, or others), teaching methods throughout the lesson (direct explanation, discussion, presentation supported with visual or audial material, or others), the relationship between science concepts with daily life and engineering design process, materials used during the instruction (computer, textbook, presentation etc.). Although there should be an independent observer to rate the observation reports in both classes, it was not possible in class environment in the present study. Therefore, the observation reports were rated by the science teacher in experimental group for 3 weeks (12 lesson hours) and by the researcher in comparison group for 3 weeks (12 lesson hours). The observation reports rated by the researcher and the teacher were analyzed, and the results of observation reports showed that the researcher followed the engineering design-based instruction, made connection with daily life experiences, encouraged the students to explore themselves and engaged them to the engineering design-based activities in the experimental group. The researcher did not use direct instruction techniques. In comparison group, the science teacher also made connection with daily life experiences, but she mostly explained the science concepts directly with some visual materials by using smartboard. However, there was no emphasize on engineering design process.

3.5. Data Analysis

Quantitative data of the study was collected by using VNOE-E and M-STEM. VNOE-E is open-ended questionnaire, so collected data was transformed quantitative data by using the rubric of “Descriptions of Nature of Engineering (NOE) Aspects” (Appendix-C) prepared by Deniz et al. (2017). Based on this rubric, responses of the participants were scored like 5-point Likert-type scale. Answer options were organized based on Table 3.10. below, which is also mentioned in Appendix-C.

Table 3.10. *A 5-point scale for Quantitative Analysis of VNOE-E*

Point	
0	No answer, incomprehensible or irrelevant answer, or an answer could not be categorized
1	An answer that is not aligned with the description of NOE aspect

Table 3.10. *A 5-point scale for Quantitative Analysis of VNOE-E (cont'd)*

2	An answer that is partially aligned with the description of NOE aspect
3	An answer that is fully aligned with the description of NOE aspect
4	An answer that is fully aligned with the description of NOE aspect. The view is well-articulated and/supported with relevant example(s)

Source: Deniz et al., 2017

The results of M-STEM were analyzed based on the information by the developers of the instrument and descriptive statistics were obtained by scoring the instrument and its subscales. Statistical analysis of collected data from 2 different instruments were made by using IBM SPSS Statistics 24.0.

For analysis of nature of engineering views of the participants, normal distribution of data gathered with VNOE-E was tested in order to decide to use parametric or nan-parametric analysis test. The value of "Shapiro-Wilks" was checked to test the normal distribution of data because of having smaller sample size than 50. If the value is bigger than alpha value (.05), the distribution of the data is normally distributed because the assumption is not violated. However, if the exact opposite situation is occurred, the assumption of the normal distribution of data is violated (Pallant, 2011). Results of VNOE-E for testing normal distribution of data is shown in Table 3.11. below.

Table 3.11. *Normal Distribution of Data Gathered with VNOE-E*

Group	**Shapiro-Wilks**		
	Statistic	***df***	***p***
Experimental Group (E)	.960	24	$.434^{*}$
Comparison Group (C)	.952	17	$.490^{*}$

$p > .05^{*}$

When the results of Table 3.11. was analyzed, each group's p values (.434 for "E" group and .490 for "C" group) are bigger than alpha value (.05). Therefore, data gathered with VNOE-E was normally distributed in both experimental and comparison group of the study. This means that parametric analysis tests could be used for analysis of the VNOE-E. One-Way ANCOVA (Analysis of Covariance) was preferred by assigning pre-test scores of VNOE-E as covariate. Therefore, before the analysis of data of VNOE-E, assumptions of ANCOVA analysis which are homogeneity of variance, measurement of covariate, linearity between dependent variable and covariate, and homogeneity of regression slopes were analyzed. Assumption of homogeneity of variance were met because significance value is bigger than alpha (.05) value as shown in Table 3.12. below. This means that each group had equal variances.

Table 3.12. *The Result of Levene Test for VNOE-E*

Levene Statistic	***df1***	***df2***	***Significance***
.012	1	39	$.915^{*}$

$p > .05^{*}$

Second assumption is measurement of covariate (it should be continuous). In VNOE-E, covariate is pre-test scores of nature of engineering views before the treatment. It is continuous, so the assumption was not also violated. Third assumption is linearity between dependent variable and covariate (they should be linear). The relationship between nature of engineering views scores before the treatment (covariate) and nature of engineering views scores after the treatment (dependent variable) was linear as shown in Figure 3.1. below, so this assumption was not also violated.

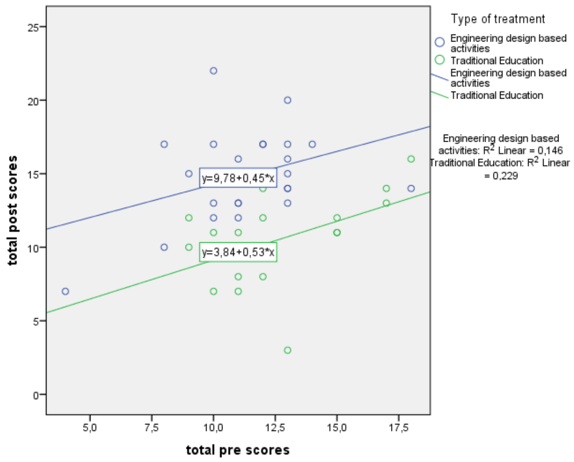

Figure 3.1. Linearity Between NOS views Before and After Treatment

Last assumption is homogeneity of regression slopes. The relationship between nature of engineering views scores before the treatment (covariate) and nature of engineering views scores after the treatment (dependent variable) for each group should be the same, in other words, they should have similar slopes. Figure 3.1. above also shows both groups have approximately similar slopes. Moreover, test of between subjects' effects could be tested for interaction between the covariate and the treatment because of unequal slopes. The result of interaction between them showed that significance value between nature of engineering views scores before the treatment (covariate) and treatment type (independent variable) is .818 which is greater than alpha level (.05) in Table 3.13. below. Therefore, there is no interaction between covariate and independent variable, and last assumption was not also violated.

Table 3.13. *Test of Between-Subjects Effects for VNOE-E*

Source	***Type III Sum of Squares***	***df***	***Mean Square***	***F***	***Significance***
Treatment	16.773	1	16.773	1.955	.170
Total pre-scores	69.968	1	69.968	8.155	.007
Treatment*Totalpre scores	.462	1	.462	.054	.818

$p > .05^*$

In conclusion, the data was appropriate for conducting One-Way ANCOVA for analysis of nature of engineering views of the participants because the assumptions supplied this conclusion.

For analysis of participants' attitudes towards STEM, firstly multivariate analysis of variance (MANOVA) was preferred by using data gathered with M-STEM. However, firstly normal distribution of data gathered with M-STEM was tested in order to decide to use parametric or nan-parametric analysis test. The value of "Shapiro-Wilks" was checked to test the normal distribution of data because of having smaller sample size than 50. Results of VNOE-E for testing normal distribution of data is shown in Table 3.14. below.

Table 3.14. *Normal Distribution of Data Gathered with M-STEM*

Group	**Shapiro-Wilks**		
	Statistic	***df***	***p***
Experimental Group (E)	.913	24	$.041^{*}$
Comparison Group (C)	.865	17	$.018^{*}$

$p < .05^{*}$

When the results of Table 3.14. was analyzed, parametric analysis test for the analysis of participants' attitudes towards STEM could not be used because p values (.041 for "E" group and .018 for "C" group) are smaller than alpha value (.05). Normal distribution of data gathered with M-STEM was violated as shown in Table 3.14. above, so the data was not appropriate for conducting MANOVA for analysis of participants' attitudes towards STEM.

Secondly, independent sample t-test which can be analyzed with gained score among pre and post scores was preferred to analyze participants' attitudes towards STEM. However, independent sample t-test was not also used for the analysis of attitudes toward STEM gathered with M-STEM because of violation of normal distribution of data in experimental group as shown in Table 3.15. below. Therefore, non-parametric statistics of independent sample t-test which is Mann-Whitney U-Test was used by analyzing gained scores among pre and post-tests of M-STEM.

Table 3.15. *Normal Distribution of Gained Scores Gathered with M-STEM*

Group	**Shapiro-Wilks**		
	Statistic	***df***	***p***
Experimental Group (E)	.810	24	$.000^{*}$
Comparison Group (C)	.897	17	$.061^{**}$

$p < .05^{*}$, $p > .05^{*}$

Qualitative data of the study was collected by using VNOE-E to support quantitative results of the study. Participants responses in pre and post VNOE-E were analyzed to generate pre and post profiles of students' views for each NOE aspect separately. Bilican (2014) categorized participants' nature of science views gathered with "Views of nature of science questionnaire (VNOS-C)" in three types; informed, adequate, or inadequate. Therefore, NOE categorization schema was formed by the researcher based on NOS categorization schema because of similarity between NOS and NOE aspects. Similar to NOS categorization schema, students' NOE views were categorized as "informed" (stating developed NOE aspect view including extended examples), "adequate" (stating a developing view but with lack of deep examples), or "inadequate" (stating a misconception or not aligned view). Moreover, another researcher who is a master student on science education and studies on STEM education also categorized students' NOE views based on this rubric. Therefore, inter-rater agreement method was used in qualitative analyses of the data because the researcher and another researcher compared and constructed their individual analyses with each other. In table 3.16., the description of the categorization of each NOE aspects are presented below.

Table 3.16. *NOE Categorization Schema*

Categorization	***Inadequate***	***Adequate***	***Informed***
Demarcation aspect	Incomprehensible or irrelevant answer about engineering	Recognition of engineering as engaging solutions for specific problems, but lack of extended explanation or examples	Recognition of engineering as engaging solutions for specific problems and inviting new technologies, and supporting that view with extended explanation or examples
Engineering design process (EDP)	Not aligned with the 4 steps of EDP (“finding a problem or need”, “researching possible solutions”, “choosing the best solution”, and “building and testing the prototype”)	Recognition of 4 steps of EDP but lack of extended explanation or examples (“finding a problem or need”, “researching possible solutions”, “choosing the best solution”, and “building and testing the prototype”)	Recognition of 4 steps of EDP (“finding a problem or need”, “researching possible solutions”, “choosing the best solution”, and “building and testing the prototype”. Also supports that view extended explanation or examples
Tentativeness	Recognition of the steps of EDP always follow in order or not aligned view about steps of EDP	Recognition of the steps of EDP do not always follow in order, but lack of extended explanation or examples	Recognition of the steps of EDP do not always follow in order and a problem solver can go back at any phase. Also supports that view extended explanation or examples
Creativity	Recognition of not playing a major role or limitation of creativity during EDP	Recognition of playing a major role of creativity during EDP, but lack of extended explanation or examples	Recognition of playing a major role of a problem solver’s creativity at any step of EDP, and supporting that view with extended explanation or examples

Table 3.16. *NOE Categorization Schema (cont'd)*

Subjectivity	Recognition of unique solution to an engineering design problem	Recognition of no unique solution to an engineering design problem, in other words there can be many solutions to the same problem, but lack of extended explanation or examples	Recognition of no unique solution to an engineering design problem, in other words there can be many solutions to the same problem because of pre-conceptions, values background, and supporting that view with extended explanation or examples.
Social and cultural aspect	Recognition of isolation of engineering from the values and norm of culture in which it is practiced	Recognition of influence of socio-cultural values on engineering design solutions, but lack of extended explanation or examples	Recognition of influence of socio-cultural values on engineering design solutions. Also supports that view extended explanation or examples
Social aspects of engineering	Recognition of engineering as a solitary pursuit and engineering design solutions are not constructed through social negotiation	Recognition of engineering design solutions are constructed through social negotiation and this enhances the quality of engineering design solutions, but lack of extended explanation or examples	Recognition of engineering design solutions are constructed through social negotiation and this enhances the quality of engineering design solutions, and supporting that view with extended explanation or examples.

For analyses of 4th question in VNOE-E (Draw a picture of an engineer at work. Describe your picture in few words, and why you drew what you drew.), written responses and drawn responses in pictures translated into words by the researcher were reviewed, and recurring ones were developed into codes. If a student mentioned that "engineers design a building and they design a car" in written response, activity of the engineer which is "builds" was coded only once, not twice. In analyses of drawn responses, gender of an engineer was analyzed firstly. The engineer having short hair was coded as male while one having long hair was coded as female. Moreover, each image or artifact in pictures was coded only once. If a picture contained both wood and stone as building materials, the code was described only once, not twice. Then, written and drawn responses were grouped into themes to get a better sense of students' drawings. For example, a student's written response was that "an engineer designs thing", the student often drew a picture including table/desk, chair, drawings, book/pencil, models.

3.6. Validity and Reliability

Validity and reliability are important for all instruments used in all studies in the literature. Validity of the study is meaningfulness, appropriateness, and usefulness of researchers' inferences based on data, while reliability of the study is the overall consistency of inferences, in other words data obtained with instruments are consistent over time, location and circumstances. Therefore, reliability and validity of M-STEM instrument which was developed before this study were examined, and other instrument's (VNOE-E) reliability and validity were conducted by the researcher. Reliability of VNOE-E was supplied depending on inter-rater agreement method with 89 percent scoring agreement with another researcher who is a master student on science education and studies on STEM education. These two different instruments were considered as appropriate and reliable to measure proposed variables.

3.6.1. Internal Validity

In all models of research, internal validity of the study is important. Internal validity means that relationship between observed variables should be accurate with what it means rather than anything else (Fraenkel, Wallen, & Hyun, 2012). There are some threats for internal validity such as location (different locations where data were collected may create a difference), implementation (implementation of treatments by different instructors may create a difference), subject characteristics (age, gender, ethnicity etc.), mortality (loss of subjects during the study), instrumentation (data collector characteristics and bias, and instrument decay), and testing (administration of pretest may create a possible testing effect) (Fraenkel et al., 2012).

To minimize subject characteristics threat for internal validity, there were two different classes in which one was comparison, while other one was experimental group in the study. These two classes were selected conveniently at total 3 different 7th grade classes in the school. Both classes had approximately the same academic achievement, socioeconomic demarcation, intelligence speed and homogeneous number in terms of gender, and so these qualifications provided the study to get appropriate and significant results.

Other threat for internal validity is mortality (loss of subjectivity). To minimize this threat, at the beginning of the study, the researcher requested the students to participate implementation of instruments in both pre and posttest. Therefore, this was not considered as significant threat because the number of participants in pre and posttest were the same in each class.

Other threat for internal validity is location. To minimize this threat, both classes approximately had the same environment during the study.

Testing can be other threat for internal validity. To minimize this threat, there were 4 weeks between pre and posttest of instruments. Therefore, administration of pretest did not create a possible testing effect on post test scores after 4 weeks.

Other threat for internal validity is instrumentation (data collector characteristics and bias, instrument decay). Instrument decay which includes the scoring procedure was minimized by analyzing qualitative instrument for validity and reliability of the instrument by two researchers. In addition, the results of two different instrument for the same participant were evaluated at different times or after completing the results of an instrument for all participants. Moreover, all instruments were applied by the same researcher to minimize data collector characteristics and bias, so this was not considered as significant threat.

However, implementation could be a threat for internal validity. There were two different instructors who are science teacher and the researcher, so their characteristics could be threat for internal validity of the study. In comparison group, curriculum-based instruction was applied by the teacher on “Force and Energy” unit, while in experimental group, engineering design-based instruction was applied by the researcher on the same unit. Although these two different classes covered the same unit but in different instructional methods, their backgrounds, pre-conceptions, values could influence the process of the instructions. Therefore, this is a limitation of the present study.

3.6.2. External Validity

External validity is the extent to which the results of a study can be generalized (Fraenkel et al., 2012). In the present study, the results of the study can be generalized to other groups having similar characteristics because convenient sampling was used to study.

3.6.3. Reliability

Reliability is the overall consistency of data obtained with instruments over time, location and circumstances. For reliability, Cronbach Alpha values was calculated for the quantitative instrument, and inter-rater agreement method was used for the qualitative instrument.

3.7. Assumptions

1) Standard conditions were supplied for the administration of the instruments.
2) All participants responded the instruments honestly and seriously.

3.8. Limitations

1) Treatments were applied by different instructors in groups, so their backgrounds, pre-conceptions, values could influence the process of the instructions.
2) The results of the present study can only be generalized to other groups having similar characteristics because of using convenient sampling.
3) There was no interview with participants in collecting qualitative data, so deeper views of participants were restricted with an open-ended questionnaire.
4) Generalization of the results might be limited because of limited sample size of the study.
5) The results of the present study were limited with the process of the treatment (3 weeks/16 lesson hours) and using two different engineering design-based activities.

CHAPTER 4

RESULTS

In this chapter, results of the data analysis are presented. There are two sections including; (1) descriptive results for “Views for Nature of Engineering-Elementary School Version (VNOE-E)” questionnaire, and (2) descriptive results for “STEM Attitude Scale: Middle School Version (M-STEM)” scale.

4.1. Descriptive Results for “Views for Nature of Engineering-Elementary School Version (VNOE-E)” Questionnaire

4.1.1. Effect of Engineering Design-Based Instruction on Students’ Nature of Engineering Views

In quantitative analyses of VNOE-E, the research question (main problem) is;

- What is the effect of engineering design-based instruction (EDBI) over curriculum-based instruction (CBI) on 7th grade students’ nature of engineering (NOE) views in Ankara?

To research the main problem about nature of engineering views of the present study, sub-problem was evaluated by conducting One-Way ANCOVA. Sub-problem is;

- Is there a significant mean difference between post-test mean scores of students taught with engineering design-based instruction (EDBI) and the students taught with curriculum-based instruction (CBI) with respect to students’ nature of engineering (NOE) views after controlling for pre-test mean scores of students?

The null hypothesis for sub-problem is;

- There is no significant mean difference between post-test mean scores of students taught with engineering design-based instruction (EDBI) and the students taught with curriculum-based instruction (CBI) with respect to students' nature of engineering (NOE) views after controlling for pre-test mean scores of students.

Descriptive statistics table of experimental and comparison group of the study for VNOE-E is presented in detail in Table 3.17. below.

Table 3.17. *Descriptive Statistics for VNOE-E Questionnaire*

Group	N	$\bar{x}_{pre}$	$\bar{x}_{post}$
Experimental (E)	24	11.25	14.83
Comparison (C)	17	12.76	10.59

When Table 3.17. was analyzed, mean values of experimental and comparison groups were close to each other before the instruction. After the instruction, mean value of the experimental group was increased, while it was decreased in comparison group. One-Way ANCOVA was used to analyze statistically significant difference between groups, and the results of this analyze is shown in Table 3.18. below.

Table 3.18. *Univariate Test and Tests of Between Subjects Effects for VNOE-E*

Dependent Variable: total post scores for VNOE-E

Group	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Significance*	*Partial Eta Squared*
Total pre-scores	69.530	1	69.530	8.311	.006	.179
Treatment	229.075	1	229.075	27.381	.000	.419

$p < .05$

When the results of Table 3.18. were analyzed, significance value (.000) is smaller than alpha level (.05), so there is a significant mean difference in nature of engineering views scores in the experimental and comparison groups after treatment, after controlling nature of engineering views scores administered prior to the treatment [F (1,38) = 27.38, p < .05]. Therefore, the null hypothesis is rejected, so this difference can be attributed to the different instructions. Moreover, when we look at the covariate (nature of engineering views before the treatment), significance value (.006), it is smaller than alpha level (.05), so it also makes difference in nature of engineering views scores in the experimental and comparison groups after treatment.

4.1.2. Changes on Nature of Engineering Aspects Regarding to Engineering Design-Based Instruction

In qualitative analyses of VNOE-E, the research question is;

- How does engineering design-based instruction (EDBI) impact 7th grade students' views about nature of engineering aspects (NOE) in Ankara?

The frequency distribution table of inadequate, adequate and informed views of students about each NOE aspect (demarcation, subjectivity, engineering design process, creativity, social and cultural embeddedness, tentativeness, and social aspects of engineering) in experimental and comparison group was analyzed in detail. Then, example quotations of students' inadequate, adequate and informed views were presented in detail.

4.1.2.1. Demarcation Aspect

In VNOE-E, three questions (2nd, 4th and 5th(b) questions) are related to demarcation aspect of NOE.

Firstly, results for 2nd question (What is engineering? What do engineers do?) about demarcation aspect of NOE were shown in Table 3.19. below.

Table 3.19. *Frequency and Percentage Values for Demarcation Aspect (2nd question) of VNOE-E Questionnaire*

Demarcation Aspect (2nd question)	*Inadequate*				*Adequate*				*Informed*			
	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%
Experimental Group (E)	7	29.0	2	8.0	17	71.0	16	67.0	0	0	6	25.0
Comparison Group (C)	3	18.0	6	36.0	10	59.0	4	23.0	4	23.0	7	41.0

When the results for 2nd question about demarcation aspect of NOE in experimental group in Table 3.19. were analyzed, 29 percent of the students held inadequate view in pre-VNOE-E; incomprehensible or irrelevant answer about engineering. Majority of the students (71 %) held adequate view; recognizing engineering as engaging solutions for specific problems, but lack of extended explanation or examples was provided. However, any student did not hold informed view; recognizing engineering as engaging solutions for specific problems and inviting new technologies, and also supporting that view with examples. Regarding students' understanding of demarcation aspect of NOE view in 2nd question of post-VNOE-E, a couple of the students (8 %) held inadequate view; incomprehensible or irrelevant answer about engineering. Like in pre-VNOE-E, majority of the students (67 %) held adequate view; recognizing engineering as engaging solutions for specific problems, but lack of extended explanation or examples was provided. 24 % of the students held informed view; recognizing engineering as engaging solutions for specific problems and inviting new technologies, and also supporting that view with examples. For instance, a student supported his view by explaining "Engineering has many types, and engineers find solutions to make people's life easier. They design planes, computers.". In brief, there was no appreciable difference in adequate view, and percentage of the students presenting inadequate view decreased as the approximate percentage of the ones maintaining informed view increase after engineering design-based instruction.

The results for 2nd question about demarcation aspect of NOE in comparison group showed that 18 percent of the students held inadequate view in pre-VNOE-E; incomprehensible or irrelevant answer about engineering. More than half of the students (59 %) held adequate view; recognizing engineering as engaging solutions for specific problems, but lack of extended explanation or examples was provided. 23 % of the students held informed view; recognizing engineering as engaging solutions for specific problems and inviting new technologies, and also supporting that view with examples. For example, a student supported his view by explaining "I think that engineering needs creativity, makes our life easier, and produces available things like computer." Regarding students' understanding of demarcation aspect of NOE view in 2nd question of post-VNOE-E, 36 percent of students held inadequate view; incomprehensible or irrelevant answer about engineering. 23 % held adequate view; recognizing engineering as engaging solutions for specific problems, but lack of extended explanation or examples was provided. 41 % held informed view; recognizing engineering as engaging solutions for specific problems and inviting new technologies, and also supporting that view with examples. In brief, there was increase in inadequate and informed views while there was decrease adequate view after curriculum-based instruction.

Example quotations of students' inadequate, adequate and informed views for 2nd question about demarcation aspect of NOE were presented in Table 3.20. below.

Table 3.20. *Example Quotations of Students' Responses to Demarcation Aspect (2nd question) in VNOE-E Questionnaire*

Group	*Instruction of VNOE-E*	*Inadequate*	*Adequate*	*Informed*
Experimental Group	Pre	"S/he is like a major manager." (Student #8)	"Engineers design something to make our life easier and to help us." (Student #15)	-

Table 3.20. *Example Quotations of Students' Responses to Demarcation Aspect (2nd question) in VNOE-E Questionnaire (cont'd)*

	Post	"Engineers make everything that they can do." (Student #8)	"Engineers find solutions for our problems." (Student #4)	"Engineering has many types, and engineers find solutions to make people's life easier. They design planes, computers." (Student #7)
Comparison Group	Pre	"Engineering has many types." (Student #30)	"Engineers produces new things for people's benefit." (Student # 34)	"I think that engineering needs creativity, makes our life easier, and produces available things like computer." (Student #27)
	Post	"I do not know." (Student #25)	"I think that they make changes in our life by using their creativity." (Student # 31)	"Engineering makes new things and changes its type; for example, some engineers study on artificial intelligence, some design robots." (Student #41)

Secondly, results for 5^{th}(b) question (How is engineering different from other subjects?) about demarcation aspect of NOE were shown in Table 3.21. below.

Table 3.21. *Frequency and Percentage Values for Demarcation Aspect (5th(b) question) of VNOE-E Questionnaire*

Demarcation Aspect (5th(b) question)	*Inadequate*				*Adequate*				*Informed*			
	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%
Experimental (E)	9	38.0	8	33.0	11	46.0	14	59.0	4	16.0	2	8.0
Comparison (C)	13	76.0	11	65.0	4	24.0	6	35.0	0	0	0	0

When the results for 5th(b) question about demarcation aspect of NOE in experimental group in Table 3.21. were analyzed, 38 percent of the students held inadequate view in pre-VNOE-E; incomprehensible or irrelevant answer about engineering. Approximately half of the students (46 %) held adequate view; recognizing engineering as engaging solutions for specific problems, but lack of extended explanation or examples was provided. 16 % held informed view; recognizing engineering as engaging solutions for specific problems and inviting new technologies, and also supporting that view with examples. Regarding students' understanding of demarcation aspect of NOE view in 5th(b) question of post-VNOE-E, 33 percent of students held inadequate view; incomprehensible or irrelevant answer about engineering. More than half of the students (59 %) held adequate view; recognizing engineering as engaging solutions for specific problems, but lack of extended explanation or examples was provided. Small part of the students (8 %) held informed view; recognizing engineering as engaging solutions for specific problems and inviting new technologies, and also supporting that view with examples. In sum, there was decrease in inadequate and informed views while there was increase adequate view engineering design-based instruction.

The results for 5th(b) question about demarcation aspect of NOE in comparison group showed that majority of the students (76 %) held inadequate view in pre- VNOE-E;

incomprehensible or irrelevant answer about engineering. 24 % of students held adequate view; recognizing engineering as engaging solutions for specific problems, but lack of extended explanation or examples was provided. However, any student did not hold informed view; recognizing engineering as engaging solutions for specific problems and inviting new technologies, and also supporting that view with examples. Regarding students' understanding of demarcation aspect of NOE view in 5th(b) question of post-VNOE-E, more than half of the students (65 percent) held inadequate view; incomprehensible or irrelevant answer about engineering. 35 % held adequate view; recognizing engineering as engaging solutions for specific problems, but lack of extended explanation or examples was provided. However, any student did not hold informed view; recognizing engineering as engaging solutions for specific problems and inviting new technologies, and also supporting that view with examples. In brief, there was no any student showing informed view, and percentage of the students presenting inadequate view decreased as the approximate percentage of the ones maintaining adequate view increase after curriculum-based instruction.

Example quotations of students' inadequate, adequate and informed views for 5th(b) question about demarcation aspect of NOE were shown in Table 3.22. below.

Table 3.22. *Example Quotations of Students' Responses to Demarcation Aspect (5th(b) question) in VNOE-E Questionnaire*

Group	*Instruction of VNOE-E*	*Inadequate*	*Adequate*	*Informed*
Experimental Group	Pre	"Each occupation has different tasks." (Student #16)	"Engineers generally design something themselves." (Student #2)	"I think that it can be different about designing because engineers design something new, but doctors operate." (Student #14)

Table 3.22. *Example Quotations of Students' Responses to Demarcation Aspect (5th(b) question) in VNOE-E Questionnaire (cont'd)*

	Post	"Engineers work in many fields." (Student #23)	"Engineering is about inventing new things and making life easier." (Student #14)	"Engineers determine people's problems, find solutions and makes a design related to best solution." (Student #4)
Comparison Group	Pre	"Engineer work than others and earn more money." (Student # 36)	"Engineers always find available solutions for people's problems." (Student #37)	-
	Post	"Engineering is too tiring and busy occupation" (Student #34)	"Engineers supply to solve many problems." (Student #29)	-

Lastly, results of students' written responses and drawings for 4th question (Draw a picture of an engineer at work. Describe your picture in few words, and why you drew what you drew.) were analyzed in three parts; analyses of written responses about an activity an engineer does at work, gender of the engineer in the drawings, and images in the drawings. Firstly, the results of activities of engineers were shown in Table 3.23.

Table 3.23. *Activities of Engineers in Students' Written Responses*

Verb	*Experimental Group*		*Comparison Group*	
	Pre	*Post*	*Pre*	*Post*
designs	25.0	42.0	12.0	6.0
draws	25.0	21.0	6.0	0.0
take notes	4.0	8.0	0.0	0.0

Table 3.23. *Activities of Engineers in Students' Written Responses (cont'd)*

fixes	8.0	8.0	18.0	12.0
controls	8.0	4.0	12.0	6.0
codes	0.0	0.0	12.0	6.0
builds	4.0	4.0	0.0	0.0
thinks	4.0	4.0	0.0	0.0
produces	4.0	0.0	6.0	0.0
measures	0.0	0.0	0.0	6.0
makes experiment	4.0	0.0	0.0	0.0

When the results of written responses about drawing an engineer at work in 4th question representing demarcation aspect of NOE were analyzed, pre-VNOE-E in experimental group showed that most popular activities engineers do were designing (25 %) or drawing (25 %) of things. For example, some of the responses were "The engineer is designing a program on computer", "The engineer is drawing houses." etc. These responses showed also their existences in post-VNOE-E with 42 % of designing and 21 % of drawing. "The engineer is designing a machine.", "The engineer is drawing a building." were the responses of some students. However, designing activity of an engineer showed appreciable increase after engineering design-based instruction while drawing activity of an engineer showed decrease. The results of students in comparison group presented that fixing (18 %), designing (12 %), controlling (12 %) and coding (12 %) were popular activities engineers do in pre-VNOE-E. For instance, "The engineer is fixing a machine.", "The engineer is coding a game." etc. They also showed their existence with their popularity in post-VNOE-E. However, they presented decrease in their existence in students' written responses.

Secondly, results of gender of the engineers in the drawings were shown in Table 3.24. below.

Table 3.24. *Gender of Engineers in Students' Drawings*

Gender	*Experimental Group*		*Comparison Group*	
	Pre	*Post*	*Pre*	*Post*
Female	21.0	4.0	24.0	6.0
Male	33.0	67.0	41.0	12.0
Unknown	46.0	29.0	35.0	82.0

Results presented that approximately half of the students (46 %) did not draw a discernable evidence about gender of the engineer in pre-VNOE-E of experimental group. 33 % of the students drew an engineer with male characteristics (short hair) while 21 % of them drew one with female characteristics (long hair). However, in post-VNOE-E, a male engineer (67 percent of students) was drawn more likely than a female engineer (4 percent of students). The result of these drawings with male engineers may be caused from working with the male engineer (the mechanical engineer) at the beginning of the engineering design-based instruction, which indicates that he had a significant impact on students' idea about engineering. Example drawings for engineer's gender were presented in Figure 3.2., Figure 3.3. and Figure 3.4. below.

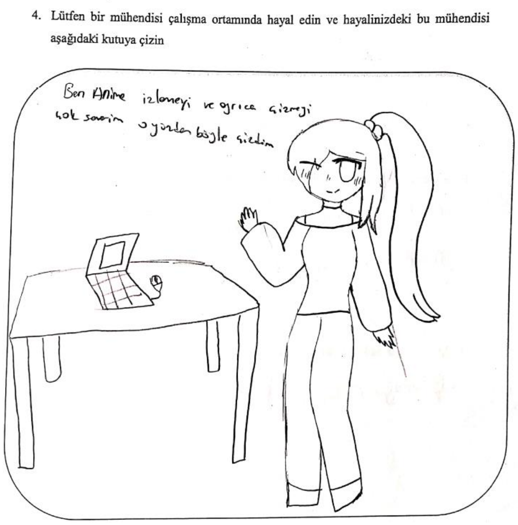

Figure 3.2. A female engineer drawing of the student coded as 1 in pre-VNOE-E

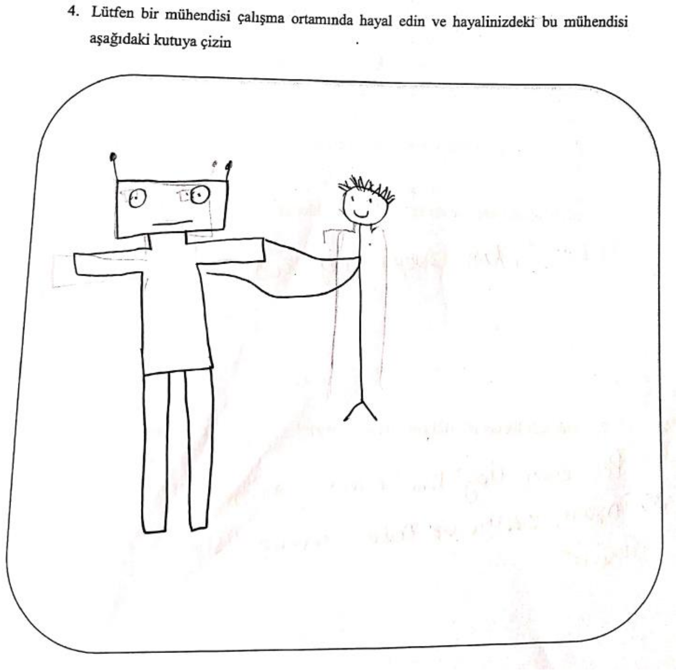

Figure 3.3. A male engineer drawing of the student coded as 9 in pre-VNOE-E

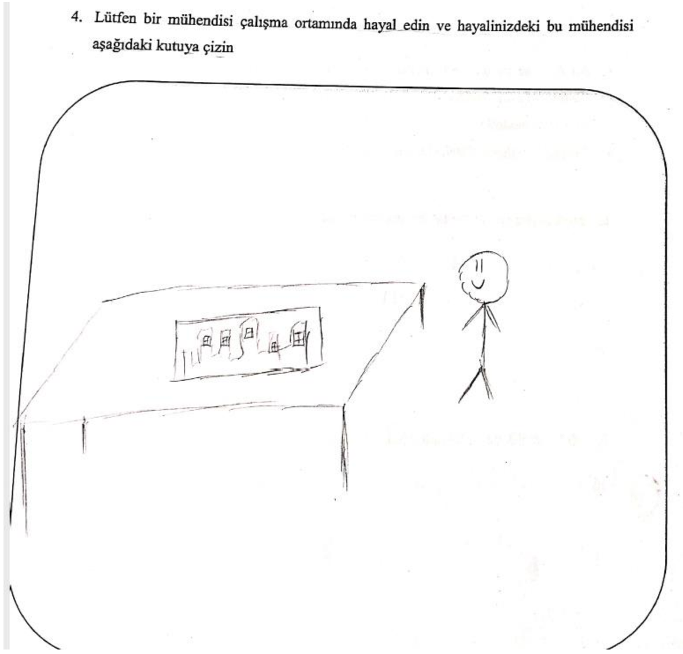

Figure 3.4. An engineer drawing with unknown gender of the student coded as 23 in pre-VNOE-E

Comparison group's pre-VNOE-E results showed that 41 % of students drew a male engineer while 24 % of them represented a female engineer in their drawings. However, 35 % of the students drew an engineer without discernable gender. Post-VNOE-E results showed that majority of the students (82 %) drew an engineer with unknown gender (neither male nor female). The students who drew an engineer with discernable gender were few; 6 % drew a female engineer while 12 % drew a male engineer. Example drawings for engineer's gender were presented in Figure 3.5., Figure 3.6. and Figure 3.7. below.

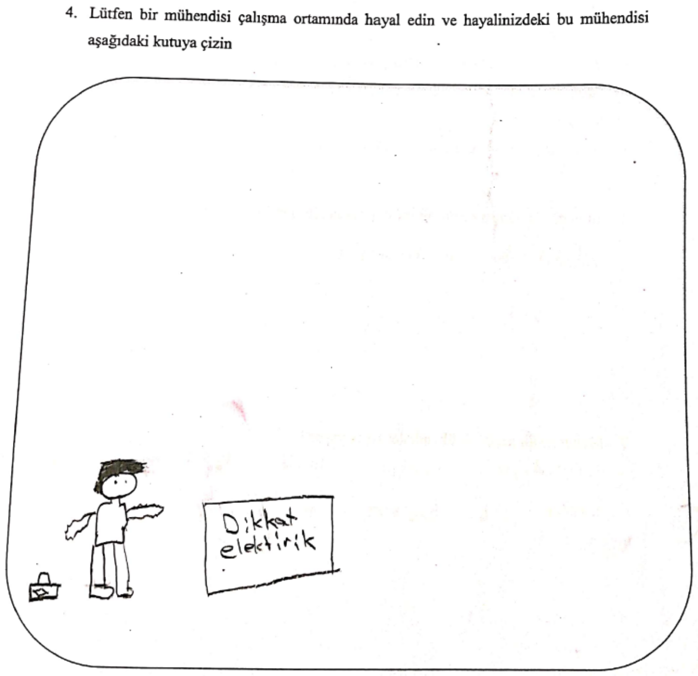

Figure 3.5. A male engineer drawing of the student coded as 39 in pre-VNOE-E

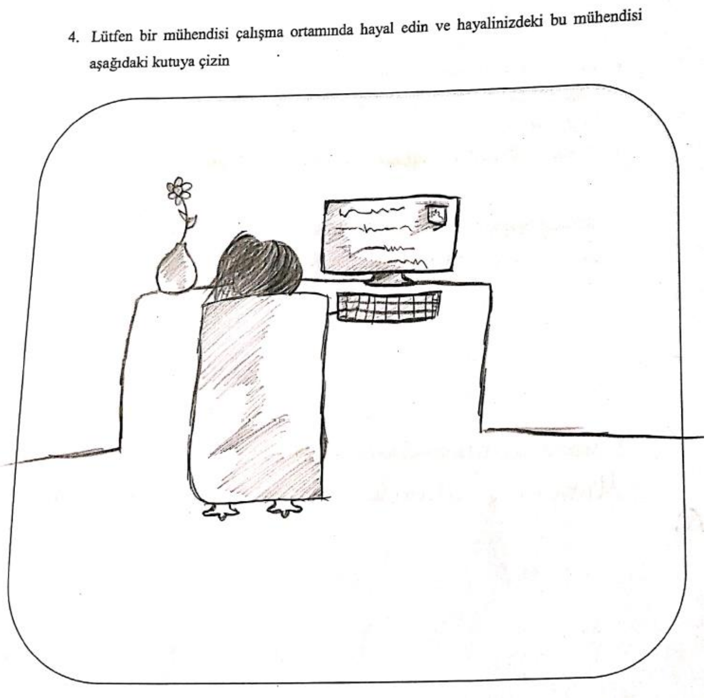

Figure 3.6. A female engineer drawing of the student coded as 35 in pre-VNOE-E

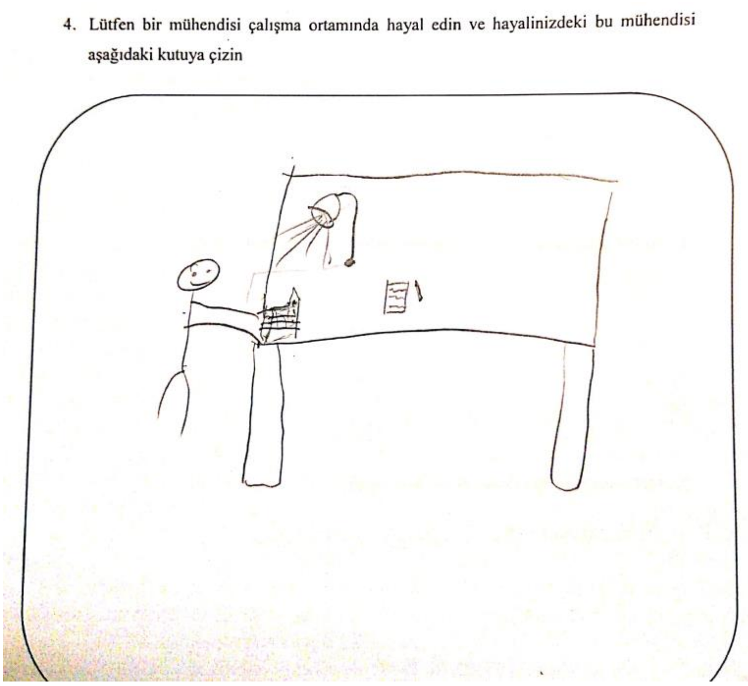

Figure 3.7. Engineer drawing with unknown gender of the student coded as 33 in post-VNOE-E

Lastly to analyze 4th question of VNOE-E, results of images in the drawings were shown in Table 3.25. below.

Table 3.25. *Common Images in Students' Drawings of Engineers*

Image	*Experimental Group*		*Comparison Group*	
	Pre	*Post*	*Pre*	*Post*
table/desk	75.0	75.0	47.0	47.0
drawing	42.0	42.0	6.0	0.0
hard hat	21.0	21.0	18.0	0.0
computer	21.0	13.0	29.0	29.0
chair	8.0	25.0	18.0	29.0
book/pencil	13.0	17.0	24.0	18.0
machine	4.0	4.0	18.0	12.0
building	4.0	17.0	12.0	17.0
model	4.0	0.0	12.0	0.0
car	0.0	0.0	12.0	12.0
building material (wood, stone, brick)	0.0	0.0	6.0	0.0
tools (nippers)	0.0	0.0	0.0	6.0

Table 3.25. presents that the most common images were table/desk (75 %), drawing (42 %), hard hat (21 %), computer (21 %), book/pencil (13 %) in experimental group before engineering design-based instruction. These images also continued in existence in students' drawings after treatment, besides chair (18 %) and building (12%) were added to pictures. Like experimental group, most common images were table/desk (47 %), computer (29 %), and book/pencil (24 %) except drawing and hard hat in comparison group. However, many images (hard hat, chair, machine, building, model, car) showed their existence with approximate frequencies in students' drawings before curriculum-based instruction. Most of these images also analyzed in drawings except hard hat, drawing and model after instruction.

Written and drawn responses were grouped into themes to get a better sense of students’ drawings. Table 3.26. demonstrated the total occurrence of the different themes by code in each group.

Table 3.26. *Frequency of Images of Engineering Grouped by Themes*

Themes	*Images Included in Group*	*Experimental Group*		*Comparison Group*	
		Pre	*Post*	*Pre*	*Post*
Images of Building/Fixing	Tools (nippers), hard hat, building materials (wood, stone, brick)	6	9	6	5
Images of Designing	Table-desk, chair, drawings, book/pencil, models, computers	39	44	23	23
Images of Products of Engineering	Cars, machines, robots, buildings	3	2	4	4

Students’ drawings of engineers introduced considerable evidence of designing in both groups. These images provided that many students think of engineers as the people who design buildings, cars, machines, robots as shown in images of products of engineering in each group in the table. These pictures included an engineer seated on a chair with holding a pen or in front of a computer. Quite few students also drew engineers in the process of building and fixing. These pictures generally included an engineer wearing a hard hat and being near a building. Example drawings for images of engineering grouped by themes were presented in Figure 3.8., Figure 3.9., Figure 3.10., and Figure 3.11. below.

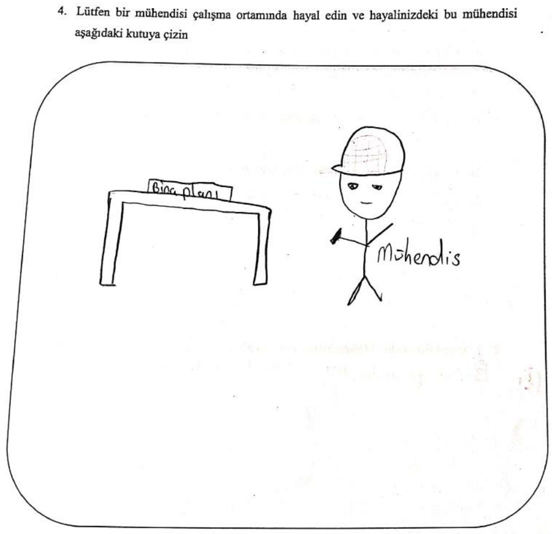

Figure 3.8. Image of Designing of the student coded as 11 in pre-VNOE-E

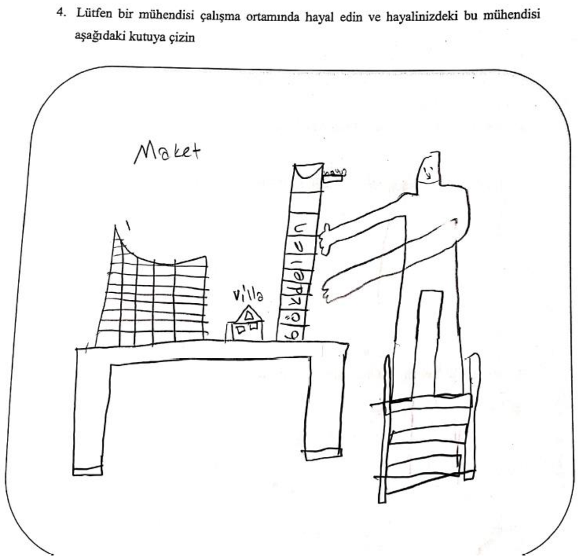

Figure 3.9. Image of Designing of the student coded as 23 in pre-VNOE-E

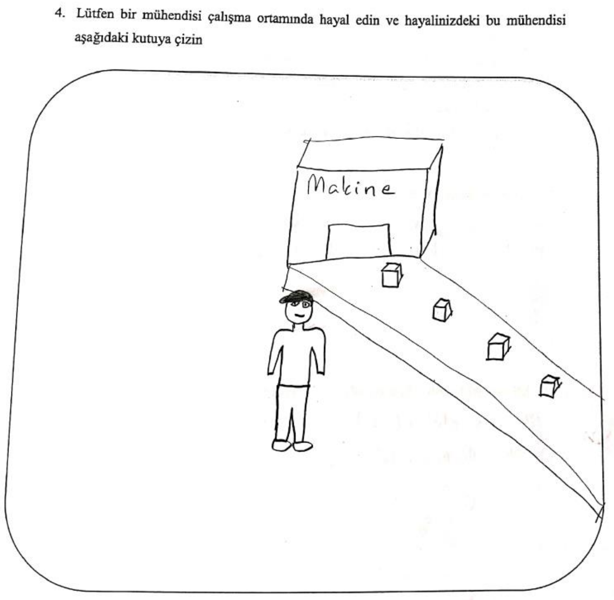

Figure 3.10. Image of Products of Engineering of the student coded as 6 in pre-VNOE-E

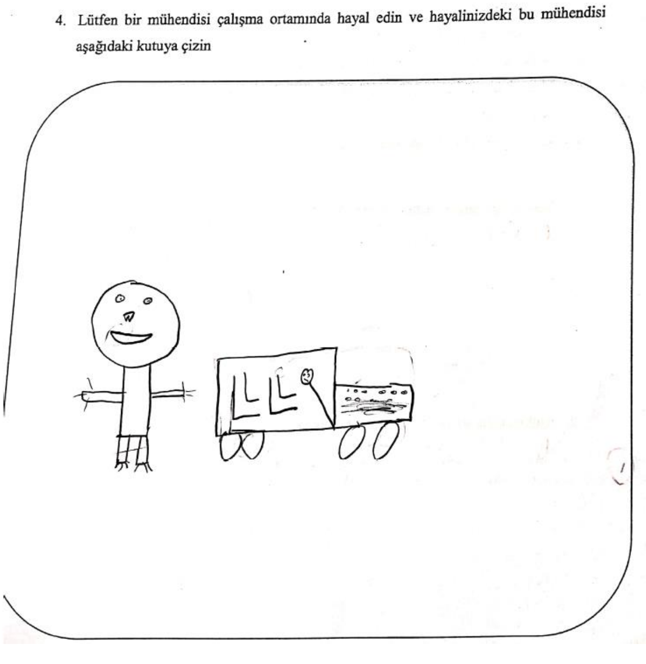

Figure 3.11. Image of Products of Engineering of the student coded as 30 in pre-VNOE-E

4.1.2.2. Engineering Design Process (EDP) Aspect

Results for engineering design process (EDP) aspect of NOE were shown in Table 3.27. below.

Table 3.27. *Frequency and Percentage Values for EDP Aspect of VNOE-E Questionnaire*

EDP aspect	*Inadequate*				*Adequate*				*Informed*			
	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%
Experimental (E)	24	100.0	17	71.0	0	0	4	17.0	0	0	3	12.0
Comparison (C)	24	100.0	24	100.0	0	0	0	0	0	0	0	0

When the results about EDP aspect of NOE in experimental group in Table 3.27. were analyzed, all the students (100 %) held inadequate view in pre-VNOE-E; not aligning 4 steps of EDP ("finding a problem or need", "researching possible solutions", "choosing the best solution", and "building and testing the prototype"). However, any student did not hold adequate or informed view; providing lack of extended explanation or examples about EDP. Regarding students' understanding of EDP aspect of NOE view in post-VNOE-E, majority the students (71 %) held inadequate view; not aligning 4 steps of EDP. 17 percent of them held adequate view; providing extended explanation for EDP, but lack of examples was provided. However, 12 percent of the students held informed view; recognizing steps of EDP and supporting that view with examples. In sum, while there was no any student showing adequate and informed views in pre-VNOE-E, their number in both views increased after engineering design-based instruction. Therefore, the number of the students presenting inadequate view decreased after engineering design-based instruction.

The results about EDP aspect of NOE in comparison group showed that all the students (100 %) held inadequate view in pre-VNOE-E; not aligning 4 steps of EDP ("finding a problem or need", "researching possible solutions", "choosing the best solution", and "building and testing the prototype"). However, any student did not hold adequate or informed view; providing lack of extended explanation or examples about EDP. Moreover, this situation was not changed in post-VNOE-E as the results showed because 100 percent of the students again held inadequate view; not aligning 4 steps of EDP. Therefore, there was no change in EDP aspect of NOE view of the students having curriculum-based instruction.

Example quotations of students' inadequate, adequate and informed views for engineering design process (EDP) aspect of NOE were presented in Table 3.28. below.

Table 3.28. *Example Quotations of Students' Responses to EDP Aspect in VNOE-E Questionnaire*

Group	*Instruction of VNOE-E*	*Inadequate*	*Adequate*	*Informed*
Experimental Group	Pre	"Yes, it reminds me about producing something before being an engineer." (Student #2)	-	-
	Post	"Yes, it is having time for producing something by engineers." (Student #20)	"Yes, it is about designing process having some steps." (Student #8)	"Yes, EDP have 4 steps; determining a problem, making research about the problem, finding the best solution for us, designing and testing. For example, we designed a building." (Student #7)

Table 3.28. *Example Quotations of Students' Responses to EDP Aspect in VNOE-E Questionnaire (cont'd)*

Comparison Group	Pre	"Yes, it is about new things, new images." (Student # 25)	-	-
	Post	"Yes, it is about possessed time to finish a project." (Student #27)	-	-

4.1.2.3. Tentativeness Aspect

Results for tentativeness aspect of NOE were shown in Table 3.29. below.

Table 3.29. *Frequency and Percentage Values for Tentativeness Aspect of VNOE-E Questionnaire*

Tentativeness aspect	*Inadequate*				*Adequate*				*Informed*			
	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%
Experimental (E)	7	29.0	3	13.0	17	71.0	21	87.0	0	0.0	0	0.0
Comparison (C)	5	30.0	3	18.0	10	58.0	14	82.0	2	12.0	0	0.0

When the results about tentativeness aspect of NOE in experimental group in Table 3.29. were analyzed, 29 percent of the students held inadequate view in pre-VNOE-E; steps of EDP always follow in order while majority of the students (71 %) of the students held adequate view; providing extended explanation about steps of EDP do not always follow in order, but lack of examples was provided. However, regarding students' understanding of tentativeness aspect of NOE view in post-VNOE-E, most of the students (87 % of students) held adequate view; providing extended explanation for tentativeness, but lack of examples was provided while 13 percent of them held inadequate view; steps of EDP always follow in order. However, in both administrations of VNOE-E, any student did not hold informed view; providing extended explanation about steps of EDP do not always follow in order and supporting that view with examples. In short, number of the students maintaining adequate view increase as number of the students presenting inadequate view decrease after engineering design-based instruction.

Table 3.29. presents that 30 percent of the students held inadequate view in pre-VNOE-E in comparison group; steps of EDP always follow in order. More than half of the students (58 %) held adequate view; providing extended explanation about steps of EDP do not always follow in order, but lack of examples was provided while 12 % of them held informed view; providing extended explanation and supporting that view with examples. However, regarding students' understanding of tentativeness aspect of NOE view in post-VNOE-E, majority of the students (82 %) held adequate view; providing extended explanation, but lack of examples about tentativeness of EDP steps was provided while 18 percent of them held inadequate view; steps of EDP always follow in order. However, any student did not hold informed view in post-VNOE-E; not providing extended explanation and examples for tentativeness of EDP steps. Briefly, number of the students presenting inadequate and informed views decrease as long as proponents of adequate view increase after curriculum-based instruction.

Example quotations of students' inadequate, adequate and informed views for tentativeness aspect of NOE were given in Table 3.30. below.

Table 3.30. *Example Quotations of Students' Responses to Tentativeness Aspect in VNOE-E Questionnaire*

Group	*Instruction of VNOE-E*	*Inadequate*	*Adequate*	*Informed*
Experimental Group	Pre	"No, I do not think." (Student #7)	"Yes, sure. When technology progresses everything progress." (Student #2)	-
	Post	"No, they do not change." (Student #8)	"Yes, because technology will improve, and our needs will change." (Student #6)	-
Comparison Group	Pre	"I think no. Because products produced by engineers do not solve our problems." (Student # 30)	"I think that solutions for our problems will change as technology progresses." (Student # 35)	"I think solutions changes because technology improves. For example; engineers have studied for speedy car nowadays and they may study on flying car in the future." (Student #39)
	Post	"Solutions will not change." (Student #25)	"Yes, technology changes everything." (Student #32)	-

4.1.2.4. Creativity Aspect

Results for creativity aspect of NOE were shown in Table 3.31. below.

Table 3.31. *Frequency and Percentage Values for Creativity Aspect of VNOE-E Questionnaire*

Creativity aspect	*Inadequate*				*Adequate*				*Informed*			
	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%
Experimental (E)	1	4.0	0	0.0	23	96.0	24	100.0	0	0.0	0	0.0
Comparison (C)	0	0.0	1	6.0	16	94.0	16	94.0	1	6.0	0	0.0

Table 3.31. presents that small part of the students (4 %) held inadequate view in pre-VNOE-E for creativity aspect of NOE in experimental group; creativity and imagination do not play a major role during EDP, and almost all of the students (96 %) held adequate view; providing extended explanation about the major role of creativity and imagination during EDP, but lack of examples. Nonetheless, any student (0 %) did not held informed view; providing extended explanation and examples about the role of creativity during EDP. Regarding students' understanding of creativity aspect of NOE view in post-VNOE-E, all of the students (100 %) held adequate view; providing extended explanation, but lack of examples about the role of creativity and imagination during EDP. However, any student (0 %) did not maintain inadequate or informed view in post-VNOE-E. Concisely, one student presenting inadequate view in pre-test changed his/her view for adequate view after engineering design-based instruction. Therefore, all students in group had adequate view for the role of creativity and imagination during EDP after engineering design-based instruction.

The results of comparison group presented that nearly all students (94 %) held adequate view in pre-VNOE-E; providing extended explanation about the major role of creativity and imagination during EDP, but lack of examples. Few students (6 %) held informed view; providing extended explanation and supporting that view with examples about the role of creativity during EDP. However, any student did not maintain inadequate view; in other words, all students believed that creativity has no a major role during EDP. Regarding students' understanding of creativity aspect of NOE view in post- VNOE-E, like in the pre-VNOE-E, nearly all students (94 %) held adequate view; providing extended explanation, but lack of examples about the role of creativity during EDP. Nonetheless, the exact opposite situation was shown about informed and inadequate views, but the same percentages. 6 percent of the students held inadequate view; creativity and imagination do not play a major role during EDP while any student (0 %) did not held informed view in post-test. In brief, percentage of the students showing adequate view did not change after curriculum-based instruction. However, while the number of the students maintaining inadequate view increase, that of ones showing informed view decrease after curriculum-based instruction.

Example quotations of students' inadequate, adequate and informed views for creativity aspect of NOE were given in Table 3.32. below.

Table 3.32. *Example Quotations of Students' Responses to Creativity Aspect in VNOE-E Questionnaire*

Group	*Instruction of VNOE-E*	*Inadequate*	*Adequate*	*Informed*
Experimental Group	Pre	"They do not use their creativity because some of them work in farms while others work in town." (Student #3)	"They use their creativity because they reveal their own ideas." (Student #19)	-
	Post	-	"They use their creativity because a project should be original." (Student #6)	-

Comparison Group	Pre	-	"They use their creativity because I think that creativity and imagination underlie engineering." (Student #27) "They use their creativity because this occupation endures them." (Student #33)	"They use their creativity because their designs are about their creativity. For example; while an engineer designs a building like a square, other designs that like a triangle." (Student #39)
	Post	"They do not use their creativity because they are bad." (Student #25)	"They use their creativity because there is creativity on the basis of engineering." (Student #27)	-

4.1.2.5. Subjectivity Aspect

Results for subjectivity aspect of NOE were shown in Table 3.33. below.

Table 3.33. *Frequency and Percentage Values for Subjectivity Aspect of VNOE-E Questionnaire*

Subjectivity aspect	*Inadequate*				*Adequate*				*Informed*			
	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%
Experimental (E)	10	42.0	9	38.0	14	58.0	15	62.0	0	0.0	0	0.0
Comparison (C)	13	76.0	11	65.0	4	24.0	6	35.0	0	0.0	0	0.0

According to results in Table 3.33., less than half of the students (42 %) in experimental group held inadequate view in pre- VNOE-E for subjectivity aspect of

NOE; recognizing unique solution to an engineering design problem, and more than half of the students (58 %) held adequate view; providing extended explanation about recognizing many solutions to the same engineering design problem, but lack of examples. Nonetheless, any student (0 %) did not held informed view; providing extended explanation and examples about the subjectivity for solutions. In post-VNOE-E, percentage of the students presenting adequate view increased a few (62 %); providing extended explanation, but lack of examples about the subjectivity for solutions while 38 percent of the students presented inadequate view; recognizing unique solution to an engineering design problem. And also, like in pre-VNOE-E, any student (0 %) did not maintain informed view in post-VNOE-E. Concisely, one student presenting inadequate view in pre-test changed his/her view for adequate view after engineering design-based instruction.

The results of comparison group indicated that majority of the students (76 %) held inadequate view in pre-VNOE-E; recognizing unique solution to an engineering design problem, and 24 % of them maintained adequate view; providing extended explanation about recognizing many solutions to the same engineering design problem, but lack of examples. Regarding students’ understanding of subjectivity aspect of NOE view in post-VNOE-E, more than half of the students (65 %) held inadequate view while 35 percent of them held adequate view. Moreover, like the result of experimental group, any student (0 %) did not present informed view in both pre- and post-VNOE-E. In brief, percentage of the students presenting inadequate view decrease while that of ones showing adequate view increase after curriculum-based instruction.

Example quotations of students’ inadequate, adequate and informed views for subjectivity aspect of NOE were shown in Table 3.34. below.

Table 3.34. *Example Quotations of Students' Responses to Subjectivity Aspect in VNOE-E Questionnaire*

Group	*Instruction of VNOE-E*	*Inadequate*	*Adequate*	*Informed*
Experimental Group	Pre	"Yes, because a hurricane tower preventing the hurricane best becomes "the best" design." (Student #10)	"No, because each engineer has different imagination and they make different designs by using their imagination." (Student #15)	-
	Post	"Yes, because "the best" choice should be made." (Student #4)	"No, because a solution may be "the best" for oneself, it means that it is subjective." (Student #1) "No, because their imagination is different from each other." (Student #9)	-
Comparison Group	Pre	"Yes, because there is always steadier one." (Student #30)	"No, because everyone has different imagination, so they cannot be monotype." (Student #27)	-

Table 3.34. *Example Quotations of Students' Responses to Subjectivity Aspect in VNOE-E Questionnaire (cont'd)*

Post	"Yes, because a solution may be better if every engineers study together." (Student #32)	"No, because solutions cannot be monotype." (Student #31) "No, because everyone has different idea, so solutions cannot be same." (Student #35)	-

4.1.2.6. Social Aspects of Engineering Aspect

Results for social aspects of engineering aspect of NOE were shown in Table 3.35. below.

Table 3.35. *Frequency and Percentage Values for Social Aspects of Engineering Aspect of VNOE-E Questionnaire*

Social aspects of engineering aspect	*Inadequate*				*Adequate*				*Informed*			
	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%
Experimental (E)	16	67.0	15	63.0	7	29.0	9	37.0	1	4.0	0	0.0
Comparison (C)	9	53.0	10	59.0	8	47.0	7	41.0	0	0.0	0	0.0

Results in Table 3.35. showed that more than half of the students (67 %) in experimental group held inadequate view in pre-VNOE-E for social aspects of engineering aspect of NOE; recognizing engineering as a solitary pursuit, not constructed through social negotiation. 29 percent of the students presented adequate view; providing extended explanation about engineering design solutions as construction through social negotiation, but lack of examples about social aspects of engineering aspect of NOE, and a small percentage of them (4 %) maintained informed view; providing extended explanation and supporting that view with examples about social aspects of engineering aspect of NOE. In post-VNOE-E, there was no remarkable change in percentage of the students presenting inadequate view (63 %); recognizing engineering as a solitary pursuit, not constructed through social negotiation while 37 percent of the students presented adequate view; providing extended explanation but lack of examples about social aspects of engineering aspect of NOE. However, any student (0%) did not maintain informed view in post-VNOE-E. In short, number of the students maintaining adequate view increase as number of the students presenting inadequate and informed views decrease after engineering design-based instruction.

Regarding the results of comparison group in pre-VNOE-E, more than half of the students (53 %) held inadequate view; recognizing engineering as a solitary pursuit, not constructed through social negotiation, and less than half of the students (47 %) maintained adequate view; providing extended explanation but lack of examples about social aspects of engineering aspect of NOE. In post- VNOE-E, 59 percent of the students held inadequate view while 41 percent of them held adequate view. Difference among these two views in post-test was much more than the results of pre-VNOE-E. Moreover, any student (0 %) did not present informed view in both pre- and post-VNOE-E. Briefly, number of the students presenting inadequate view increase as long as proponents of adequate view decrease after curriculum-based instruction.

Example quotations of students' inadequate, adequate and informed views for social aspects of engineering aspect of NOE were indicated in Table 3.36. below.

Table 3.36. *Example Quotations of Students' Responses to Social Aspects of Engineering Aspect in VNOE-E Questionnaire*

Group	*Instruction of VNOE-E*	*Inadequate*	*Adequate*	*Informed*
Experimental Group	Pre	"They work alone because they may have distractibility when there is someone around them." (Student #14)	"They work in group." (Student #22)	"They work in group. For example, a satellite sent to the space is produced by many engineers." (Student #9)
	Post	"They work alone because they may be confused when they work in group." (Student #14)	"They work in group, and everyone indicates their own idea." (Student #7)	-
Comparison Group	Pre	"They work alone because they think better when they are alone." (Student #31)	"They work in group, and they design, draw and make together. If there is a problem, they solve together." (Student #41)	-
	Post	"They work alone because they need concentration." (Student #34)	"They work in group because they make information exchange among them." (Student #32)	-

4.1.2.7. Social and Cultural Embeddedness Aspect

Results for social and cultural embeddedness aspect of NOE were shown in Table 3.37. below.

Table 3.37. *Frequency and Percentage Values for Social and Cultural Embeddedness Aspect of VNOE-E Questionnaire*

Social and cultural embeddedness aspect	*Inadequate*				*Adequate*				*Informed*			
	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%	f_{pre}	%	f_{post}	%
Experimental (E)	9	38.0	6	25.0	12	50.0	15	63.0	3	12.0	3	12.0
Comparison (C)	6	35.0	6	35.0	8	47.0	10	59.0	3	18.0	1	6.0

Table 3.37. *Frequency and Percentage Values for Social and Cultural Embeddedness Aspect of VNOE-E Questionnaire (cont'd)*

According to the results of pre-VNOE-E for experimental group in Table 3.37., 38 percent of the students held inadequate view for social and cultural embeddedness aspect of NOE; recognizing no interaction between engineering and society. Half of the students (50 %) presented adequate view; providing extended explanation about interaction between engineering and society, but lack of examples. In post-VNOE-E, there was decrease in number of the students presenting inadequate view (25 %) regarding pre-VNOE-E; recognizing no interaction between engineering and society. Conversely, there was increase in number of the students maintaining adequate view (63 %); providing extended explanation about interaction between engineering and society but lack of examples. Moreover, in both pre- and post-VNOE-E, 12 percent of the students maintained informed view; providing extended explanation and supporting that view with examples about social and cultural embeddedness aspect of NOE. In sum, engineering design-based instruction decreased percentage of the students having inadequate view while increase that of ones having adequate view.

The results of comparison group in pre-VNOE-E, less than half of the students (47 %) held adequate view; providing extended explanation about interaction between engineering and society, but lack of examples and 18 % of them maintained informed view; providing extended explanation and supporting that view with examples. In post- VNOE-E, there was increase in number of the students holding adequate view (59 %) while there was decrease in number of the students holding informed view (6 %). In addition, there was no change in number of the students presenting inadequate view because 35 percent of the students maintained that view in both pre- and post-VNOE-E. In brief, curriculum based-instruction increase percentage of the students maintaining adequate view while decrease that of ones having informed view.

Example quotations of students' inadequate, adequate and informed views for social and cultural embeddedness aspect of NOE were given in Table 3.38. below.

Table 3.38. *Example Quotations of Students' Responses to Social and Cultural Embeddedness Aspect in VNOE-E Questionnaire*

Group	*Instruction of VNOE-E*	*Inadequate*	*Adequate*	*Informed*
Experimental Group	Pre	"Engineering design solutions affect our life negatively." (Student #16) "Engineering design solutions do not affect our life." (Student #18)	"They make our life easier." (Student #6) "They affect our life positively." (Student #20)	"They make our life easier like computers, so we can find information easily with computers." (Student #10)

Table 3.38. *Example Quotations of Students' Responses to Social and Cultural Embeddedness Aspect in VNOE-E Questionnaire (cont'd)*

	Post	"I do not know." (Student #13) "They are harmful in some fields." (Student #22)	"They make our life easier and provide to live comfortably." (Student #6)	"We can learn more information when computers have been developed, and we can be in safe when bridges have been developed." (Student #1)
Comparison Group	Post	"I do not know." (Student #13) "They are harmful in some fields." (Student #22)	"They make our life easier and provide to live comfortably." (Student #6)	"We can learn more information when computers have been developed, and we can be in safe when bridges have been developed." (Student #1)
	Post	"Our life may happen worse, we may have some challenges." (Student #40)	"They make our life easier." (Student #30)	"They affect our life positively, for example; computers provide us both information and fun." (Student #36)

4.2. Descriptive Results for "STEM Attitude Scale: Middle School Version (m-STEM)" Questionnaire

In quantitative analyses of M-STEM, the research question (main problem) is;

- ➢ What is the effect of engineering design-based instruction (EDBI) over curriculum-based instruction (CBI) on 7th grade students' attitudes towards STEM in Ankara?

To research the main problem about attitudes towards STEM of the present study, sub-problem was evaluated by conducting Mann-Whitney U test. Sub-problem is;

- ➢ Is there a significant difference between gained attitude scores of students taught with engineering design-based instruction (EDBI) and the students taught with curriculum-based instruction (CBI) with respect to students' attitudes towards STEM?

The null hypothesis for sub-problem is;

- ➢ There is no significant difference between gained attitude scores of students taught with engineering design-based instruction (EDBI) and the students taught with curriculum-based instruction (CBI) with respect to students' attitudes towards STEM.

Test statistics table of experimental group receiving engineering design-based instruction and comparison group receiving curriculum-based instruction for M-STEM as the result of Mann-Whitney U test was presented in detail in Table 3.39. below.

Table 3.39. *Test Statistics for M-STEM Questionnaire*

	Total Attitudes
Mann-Whitney U	166.000
Wilcoxon W	319.000
Z	-1.006
Asymp. Sig. (2-tailed)	.314

Grouping Variable: Type of treatment

When Table 3.39. was analyzed, the z value is -1.01 (rounded) with a significance level (p) of p =.31. The probability value (p) is not less than or equal to .05, so the result is not significant. Therefore, the null hypothesis is retained, and there is no statistically significant difference in the gained attitude scores of experimental and comparison groups.

Effect size statistic (r) can be approximately calculated by using z and N values given in tables above (Cohen, 1988). Effect size was calculated as r = .00 by using r = z/square root of N where N = total number of cases. This would be considered no effect size using Cohen (1988) criteria of .1 = small effect, .3 = medium effect, .5 = large effect.

Instead of comparing means of the two groups, as in the case of t-test, the Mann-Whitney U test compares medians. Median values of each group were shown in detail in Table 3.40. below.

Table 3.40. *Median Values of Groups in M-STEM Questionnaire*

Gained Score

Type of Treatment	*N*	*Median*
Engineering design-based instruction	24	2.00
Curriculum based-instruction	17	-1.00
Total	41	1.00

A Mann-Whitney U Test revealed no significant difference in the attitudes of experimental group receiving engineering design-based instruction (Md = 2.0, n = 24) and comparison group receiving curriculum-based instruction (Md = -1.0, n = 17), U = 166.0, z = -1.01, p = .31, r = .00.

M-STEM has 4 sub-dimensions including mathematics, science, engineering and 21st century skills. Results of these sub-dimensions were analyzed in terms of agreement percentages for items and change in mean scores among pre and post administration in detail.

4.2.1. Mathematics

Results for mathematics sub-dimension of M-STEM were shown in Table 3.41. below.

Table 3.41. *Agreement Percentages for Items and Mean Scores in Mathematics Sub-dimensions of M-STEM*

Item	*Experimental Group*		*Comparison Group*	
	Pre	*Post*	*Pre*	*Post*
1. Math has been my worst subject.	62.5	54.1	76.5	82.4
2. I would consider choosing a career that uses math.	54.2	66.7	47.0	47.0
3. Math is hard for me.	66.7	62.5	70.6	70.6
4. I am the type of student to do well in math.	62.5	75.0	58.8	58.8
5. I can handle most subjects well, but I cannot do a good job with math.	58.3	70.8	70.6	76.4
6. I am sure I could do advanced work in math.	54.1	54.1	47.1	58.8
7. I can get good grades in math.	75.0	79.2	82.3	64.7
8. I am good at math.	62.5	70.8	63.7	58.8
Mean Scores of Mathematics	*29.33*	*31.04*	*30.29*	*29.29*

In experimental group, the results showed that agreement percentages for items 2, 4, 7 and 8 increased after engineering design-based instruction. Moreover, agreement percentages in reverse items which are item 1 and 3 decreased after instruction. In general, mean score in pre-test (29.33) increased to 31.04 in post-test in experimental group after engineering design-based instruction.

Regarding the results of comparison group having curriculum-based instruction, agreement percentages for items 2, 4, 7 and 8 decreased except item 6 after instruction. Moreover, agreement percentages in reverse items which are item 1 and 5 increased except item 3 after instruction. In general, mean score in pre-test (30.29) decreased to 29.29 in post-test in comparison group after curriculum based-instruction.

4.2.2. Science

Results for science sub-dimension of M-STEM were shown in Table 3.42. below.

Table 3.42. *Agreement Percentages for Items and Mean Scores in Science Sub-dimension of M-STEM*

Item	*Experimental Group*		*Comparison Group*	
	Pre	*Post*	*Pre*	*Post*
1. I am sure of myself when I do science.	87.5	70.8	70.6	58.8
2. I would consider a career in science.	58.3	58.3	58.8	53.0
3. I expect to use science when I get out of school.	58.3	75.0	64.7	47.1
4. Knowing science will help me earn a living.	83.3	83.3	76.5	70.6
5. I will need science for my future work.	83.4	79.2	70.6	53.0
6. I know I can do well in science.	91.7	83.4	64.7	70.6
7. Science will be important to me in my life's work.	87.5	70.8	63.7	53.0

Table 3.42. *Agreement Percentages for Items and Mean Scores in Science Sub-dimension of M-STEM (cont'd)*

8. I can handle most subjects well, but I cannot do a good job with science.	91.7	79.2	88.2	82.4
9. I am sure I could do advanced work in science.	58.3	62.5	34.3	47.1
Mean Scores of Science	*38.21*	*37.29*	*32.88*	*30.82*

Table 3.42. shows that agreement percentages in experimental group for items 3 and 9 increased after engineering design-based instruction. However, they presented decrease in items 1, 5, 6 and 7. In addition, there was also decrease of agreement percentages in reverse item which is item 8. In general, mean score in pre-test (38.21) decreased to 37.29 in post-test in experimental group after engineering design-based instruction.

The results of comparison group having curriculum-based instruction presented that agreement percentages for items 6 and 9 increased after instruction. Nonetheless, they showed decrease in items 1, 2, 3, 4, 5 and 7. In addition, there was also decrease of agreement percentages in reverse item which is item 8. In general, mean score in pre-test (32.88) decreased to 30.82 in post-test control group after curriculum based-instruction.

4.2.3. Engineering

Results for engineering sub-dimension of M-STEM were shown in Table 3.43. below.

Table 3.43. *Agreement Percentages for Items and Mean Scores in Engineering Sub-dimension of M-STEM*

Item	*Experimental Group*		*Comparison Group*	
	Pre	*Post*	*Pre*	*Post*
1. I like to imagine creating new products.	95.8	83.3	70.6	82.4
2. If I learn engineering, then I can improve things that people use every day.	62.5	79.1	70.6	82.3
3. I am good at building and fixing things.	66.6	66.6	23.5	35.3
4. I am interested in what makes machines work.	62.5	66.7	35.3	17.7
5. Designing products or structures will be important for my future work.	50.0	62.5	70.5	53.0
6. I am curious about how electronics work.	66.7	70.9	52.9	35.3
7. I would like to use creativity and innovation in my future work.	75.0	70.8	58.8	53.0
8. Knowing how to use math and science together will allow me to invent useful things.	70.8	75.0	64.7	47.1
9. I believe I can be successful in a career in engineering.	41.7	41.7	29.4	23.5
Mean Scores of Engineering	*34.50*	*34.33*	*30.71*	*29.00*

As shown in Table 3.43., agreement percentages in experimental group for items 2, 4, 5, 6, and 8 increased after engineering design-based instruction. However, they presented decrease in items 1 and 7. In addition, there was also no change in agreement percentages in items 3 and 9. In general, there was unobtrusive decrease in mean score from 34.50 in pre-test to 34.33 in post-test in experimental group after engineering design-based instruction.

Agreement percentages of comparison group having curriculum based-instruction in items 1, 2, and 3 presented increase while other items which are 4, 5, 6, 7, 8 and 9 showed decrease. Generally, there was decrease in mean score from 30.71 in pre-test to 29.00 in post-test in comparison group after curriculum based-instruction.

4.2.4. 21st Century Skills

Results for 21st century skills sub-dimension of M-STEM were shown in Table 3.44. below.

Table 3.44. *Agreement Percentages for Items and Mean Scores in 21st Century Skills Sub-dimension of M-STEM*

Item	*Experimental Group*		*Comparison Group*	
	Pre	*Post*	*Pre*	*Post*
1. I am confident I can lead others to accomplish a goal.	62.5	75.0	41.1	58.8
2. I am confident I can encourage others to do their best.	83.3	83.3	35.3	58.8
3. I am confident I can produce high quality work.	62.5	79.2	35.3	52.9
4. I am confident I can respect the differences of my peers.	87.5	91.6	64.7	70.6

Table 3.44. *Agreement Percentages for Items and Mean Scores in 21st Century Skills Sub-dimension of M-STEM (cont'd)*

5. I am confident I can help my peers.	83.4	87.5	58.8	58.8
6. I am confident I can include others' perspectives when making decisions.	91.7	91.7	70.6	58.8
7. I am confident I can make changes when things do not go as planned.	70.8	87.5	52.9	41.1
8. I am confident I can set my own learning goals.	75.0	79.2	58.8	70.6
9. I am confident I can manage my time wisely when working on my own.	70.8	75.0	47.1	52.9
10. When I have many assignments, I can choose which ones need to be done first.	87.5	83.3	64.7	70.6
11. I am confident I can work well with students from different backgrounds.	79.1	75.0	64.7	47.0
Mean Scores of 21st Century Skills	*46.00*	*46.38*	*38.65*	*38.47*

Regarding the results of Table 3.44., the students having engineering design-based instruction showed increase in items 1, 3, 4, 5, 7, 8 and 9. Nonetheless, there was decrease in items 10 and 11. Also, they showed no change in items 2 and 6. In general, there was increase in mean score from 46.00 in pre-test to 46.38 in post-test in experimental group after engineering design-based instruction.

Agreement percentages of the students having curriculum based-instruction in items 1, 2, 3, 4, 8, 9, and 10 presented increase while other items which are 6, 7, and 11 showed decrease. Moreover, there was no change in agreement scores in item 5. Generally, there was decrease in mean score from 38.65 in pre-test to 38.47 in post-test in comparison group after curriculum based-instruction.

4.3. Summary of the Results

The results of the study revealed that;

- There was a significant difference in nature of engineering views of students receiving engineering design-based instruction and others receiving curriculum-based instruction.
- For demarcation aspect of NOE views, percentage of the students presenting inadequate view decreased as the approximate percentage of the ones maintaining informed view increased after engineering design-based instruction. Nonetheless, in comparison group, there was increase in inadequate and informed views while there was decrease adequate view after curriculum-based instruction.
- Images of engineering of students having engineering design-based instruction were developed by themes while there was decrease or no change in students' development about images of engineering having curriculum-based instruction.
- Majority of the students held inadequate view for engineering design process (EDP) aspect of NOE views before engineering design-based instruction, and percentage of students presenting adequate or informed views increased after engineering design-based instruction. However, there was no change in inadequate views of students in comparison group after curriculum-based instruction.
- In tentativeness aspect of NOE views, most of the students presented adequate view before instruction, and this situation was also observed after engineering design-based instruction. In addition, percentage of students showing inadequate view decreased after instruction. In comparison group, more than

half of the students showed adequate view, and percentage of this view increased while inadequate and informed views decreased after curriculum-based instruction.

- For creativity aspect of NOE views, approximately all students presented adequate view and a student showed inadequate view before instruction. However, all students in group had adequate view for the role of creativity and imagination during EDP after engineering design-based instruction. In comparison group, percentage of the students showing adequate view did not change after curriculum-based instruction. However, while the number of the students maintaining inadequate view increased, that of ones showing informed view decreased after curriculum-based instruction.
- In subjectivity aspect of NOE view, small percentage changes occurred in inadequate and adequate views after engineering design-based instruction. In brief, percentage of the students presenting inadequate view decreased while that of ones showing adequate view increased after instruction. Moreover, this situation was also seen in comparison group having curriculum-based instruction.
- For social aspects of engineering aspect of NOE view, more than half of the students maintained inadequate view. However, percentage of the students maintaining adequate view increased as number of the students presenting inadequate and informed view decreased after engineering design-based instruction. Nonetheless, number of the students presenting inadequate view increased as long as proponents of adequate view decreased after curriculum-based instruction in comparison group.
- In social and cultural embeddedness aspect of NOE view, half of the students showed adequate view before instruction. Engineering design-based instruction decreased percentage of the students having inadequate view while increased that of ones having adequate view. In comparison group, curriculum

based-instruction increased percentage of the students maintaining adequate view while decreased that of ones having informed view.

- There was no significant difference in attitudes towards STEM of students receiving engineering design-based instruction and others receiving curriculum-based instruction.
- The students taught with engineering design-based instruction presented increase in mathematics and 21st century skills sub-dimensions while showed unobtrusive decrease in engineering and science. Nonetheless, others taught with curriculum based-instruction presented decrease in all sub-dimensions; mathematics, science, engineering and 21st century skills.

CHAPTER 5

DISCUSSIONS, CONCLUSIONS, IMPLICATIONS, RECOMMENDATIONS

In this chapter, the major results of the present study are discussed in the light of related literature. In addition, implications and recommendations for further studies are also addressed in the closure of the chapter.

5.1. Discussions

In this part, the results of the present study were discussed. The purpose of the study was to investigate the effect of engineering design-based instruction on students' NOE views; changes on NOE aspects regarding to engineering design-based instruction; and the effects of engineering design-based instruction on students' attitudes towards STEM. For this reason, students' NOE views and attitudes towards STEM were determined by two different valid and reliable questionnaires. Then, statistical analyses were conducted to investigate the effect of engineering design-based instruction on students' NOE views and attitudes towards STEM. Moreover, change on students' views for each NOE aspect was analyzed qualitatively.

In the following sections, the effect of engineering design-based instruction on students' NOE views; changes on NOE aspects regarding to engineering design-based instruction; and the effects of engineering design-based instruction on students' attitudes towards STEM were discussed respectively based on the findings of the present study.

5.1.1. Nature of Engineering Views

Research Question 1: What is the effect of engineering design-based instruction (EDBI) over curriculum-based instruction (CBI) on 7th grade students' nature of engineering (NOE) views in Ankara?

In the present study, the effect of engineering design-based instruction on 7th grade students' NOE views were determined by VNOE-E questionnaire. Results of the study presented that there was a significant difference in nature of engineering views of 7th

grade students receiving EDBI and others receiving CBI after treatments. The study followed pre- and post-test design and a comparison group was included to investigate the effectiveness of engineering design-based instruction. Mean values of experimental and comparison groups were close to each other before the instruction. However, the difference between them after the instructions more rather than that before the treatments. Moreover, mean value of the experimental group was increased, while it was decreased in comparison group after the instruction. Therefore, it can be concluded that the differences between groups can be explained by use of different instructions. Engagement in engineering design-based instruction (EDBI) and explicitly emphasizing engineering design process (EDP) with activities might have helped them increase their nature of engineering (NOE) views. In a similar vein, the results of previous studies showed the positive effect of engineering design-based instruction on students' academic achievement, attitude, motivation, science learning, and engineering design process steps (Yıldırım & Altun, 2015; Guzey et al., 2016; Roth, 2001; and Altaş, 2018), and integration of engineering in curriculum increases students' academic achievement, 21st century skills, motivation towards learning science and their attitudes toward STEM (Moore et al., 2015). In addition, students' interest in science and engineering can be increased by teaching science with engineering design-based instruction (NAE & NRC, 2014). Moreover, Yeşilyurt and others (2019) investigated the effect of engineering design experience on NOE views of elementary students (grades 3-5). According to the study, participating in a Saturday STEM School Program for five weeks including an engineering design challenge improved NOE views of elementary students. Students were administered the VNOE-E both at the beginning and at the end of the treatment. In data analysis, responses were analyzed based on the NOE framework describing each NOE aspects developed by the authors (Deniz, Yeşilyurt, Kaya & Trabia, 2017). The NOE framework was developed by adapting NOS research framework in their previous study (Deniz, Yeşilyurt, Kaya & Trabia, 2017). They pointed out that similarity between NOS and NOE aspects like tentativeness, subjectivity, socially and culturally embeddedness etc. except engineering design process (EDP). The result of the study presented that elementary students' NOE views were changed positively after participating in Saturday STEM School Program including an engineering design challenge. In addition, the result of the present study is consistent with the results of previous researches about engineering views which were stated in literature review chapter (Deniz, Yeşilyurt, Kaya & Trabia, 2017; Yeşilyurt et a., 2019; Yıldırım & Türk, 2018; Altaş, 2018; & Ercan, 2014). In addition, a similar study was conducted by Deniz, Yesilyurt, Kaya and Trabia (2017) with elementary teachers. The teachers participated in engineering professional development program for 3 days (6 hours per day) in which they were instructed with engineering design process as a real-life example, creativity during engineering design and other NOE aspects, and then they constructed a soda can crusher in groups based on engineering design process. This study also showed that elementary teachers' NOE views were changed positively after participating in a professional development program including an authentic engineering design challenge (Deniz et al., 2017). In the present study, the mechanical engineer's sharing of their occupational experiences was especially valuable in enriching the world context of the activities through EDBI. Therefore, the students experienced engineering with the mechanical engineer (demarcation criteria). Creativity and subjectivity aspects of NOE were also experienced with engineering design process steps and different designs of final prototypes of each group. The activites prepared based on EDP steps enabled the students to experience engineering design process (EDP) aspect of NOE. Besides, tentativeness aspect was emphasized during the activities because of redesign of the prototype or EDP step. In addition, the students were also experienced social and cultural embeddedness aspect of NOE because of economic factors (criteria and constraints) on engineering design solutions and the effects of solutions on the daily life. Therefore, the difference in NOE views between groups might be attributed to the positive effect of engineering design-based instruction. As Yeşilyurt et al. (2019) emphasized that first-hand experience in engineering design challenges can improve elementary students' NOE views.

In summary, there was significant effect of engineering design-based instruction on 7th grade students NOE views positively. Students taught with engineering design-based instruction showed significant development in their nature of engineering views. However, the students taught with curriculum-based instruction did not show any development in their nature of engineering views, in fact they showed decrease in that because they did not experience any aspect of NOE in curriculum-based instruction (CBI). This result may be explained with the lack of an explicit instruction of NOE as explained in previous studies (Yeşilyurt et al., 2019; Deniz et al., 2017). They explained that NOE ideas should be explicitly introduced to the students by the teachers like explicit NOS instruction.

5.1.2. Change in Nature of Engineering Views

Research Question 2: How does engineering design-based instruction (EDBI) impact 7th grade students' views about nature of engineering aspects (NOE) in Ankara?

In the present study, how the students' views for each NOE aspect change with engineering design-based instruction (EDBI) were examined by using VNOE-E questionnaire. The participants' views for each aspect (demarcation criteria, creativity, engineering design process, subjectivity, social and cultural embeddedness, tentativeness, and social aspects of engineering) were evaluated as inadequate, adequate or informed view based on "NOE categorization schema" (Table 3.14.) developed by the researcher in experimental and comparison groups in detail.

Results of the study showed that majority of the students held adequate and informed views of demarcation criteria (92 %), creativity (100 %), and social and cultural embeddedness (75 %) aspects of NOE after engineering design-based instruction. Moreover, percentage of the students showing inadequate views decreased after the instruction. In the literature, similarity between NOS and NOE aspects was pointed out by some studies (Deniz et al., 2017; Yeşilyurt et al., 2019). As the results of many previous studies also showed that most of the participants held inadequate views of some NOS aspects without receiving NOS instruction (e.g., Abd-El-Khalick, 2005;

Mıhladız, & Doğan, 2012), so eliminating inadequate views of demarcation criteria, creativity and social and cultural embeddedness aspects might be limited with these engineering design-based activities because of developing the activities based on EDP steps. Therefore, there might be more emphasize on these NOE aspects during EDBI. In comparison group, there were no improvement in their adequate and informed views of these aspects of NOE, in fact there was decrease or no change in their views because of not receiving EDBI. This study investigated the effectiveness of the EDBI, so followed pre- and post-test design. Therefore, it can be concluded that receiving EDBI and explicitly emphasizing NOE aspects might improve the NOE views of the students. This can be supported with the fact that participants improved their views of various NOE aspects after receiving an explicit instruction of NOE by previous researches (Deniz et al., 2017; Yeşilyurt et al., 2019).

It can be concluded that the students' opinions about engineer and engineering discipline (demarcation criteria) was developed positively after EDBI. They recognized that engineering is about engaging solutions for specific problems, and some of the students (25 %) were successful in giving examples for their opinions. For example, some quotations were "Engineers design something to make our life easier and to help us.", "Engineering has many types, and engineers find solutions to make people's life easier. They design planes, computers." etc. The results of previous studies also showed the positive effect of STEM Education or engineering design-based instruction on views about engineer or engineering discipline (Yeşilyurt et al., 2019; Deniz et al., 2017; Yıldırım &Türk, 2018; Altaş, 2018; and Ercan, 2014). In the present study, the students experienced engineering by working with the mechanical engineer and engineering design process. Therefore, the high percentages of participants with adequate and informed views of demarcation aspect might be caused from working with the mechanical engineer at the beginning of the engineering design-based instruction, which indicates that he had a significant impact on students' idea about engineering.

Moreover, when the engineer drawings of the students in terms of images in the drawings and gender of the engineer were analyzed, the participants developed more their drawings in designing or building/fixing themes after EDBI. In the drawings, tools (nippers), hard hat, and building materials (wood, stone, brick) were drawn as images of building/fixings before EDBI. The same theme also showed its existence with increasing in the number of frequencies of these images after EDBI. According to these drawings, the engineer generally wearing hard hat have building materials in near. Besides these images, table-desk, chair, drawings, book/pencil, models, and computers were also observed as images of designing in the drawings before EDBI. They also showed development in frequencies about the images of designing after EDBI. In the drawings, the engineer sitting on a chair draw a design by pencil or computer. The result of previous study showed that drawings of the students showed considerable evidence for the themes of images about building/fixing and designing without any intervention (Knight & Cunningham, 2004). Moreover, in the present study, engineering design-based instruction (EDBI) improved more the students' drawings in designing and building/fixing themes. In addition to images, EDBI had an effect on the participants' views for gender of an engineer. The percentage of the students' drawing of male engineer was increased, and more than half of the participants drew a male engineer. These results might be caused from working with the male engineer and his projects about designing at the beginning of the engineering design-based instruction, which indicates that he had a significant impact on students' idea about engineering. The results of previous study also showed the effect of working with two female undergraduate engineering students in students' drawings because their drawings presented that significant difference in the number (22 % of difference) between a female and male engineer. There was mostly a female engineer than male after working with the female engineering students for a few months before the research (Knight & Cunningham, 2004).

In creativity aspect of NOE, the students' opinions about the role of creativity and imagination during EDP was developed positively after EDBI. All students held adequate view of this aspect after the instruction and presented that creativity and imagination play a major role of at any step of engineering design process. Working in small groups to solve daily life problems and observing different types of prototype designs, materials etc. at the end of the activities provided the students to recognize that every participant in the groups have different creativity and imagination because of choosing different materials, designs etc. The results of previous study showed that STEM activities based on daily life problems improved their motivation towards courses and creativity, and also for their social life like career choices (English, Hudson & Dawes, 2013; English, 2018; Fan & Yu, 2015; Uğraş, 2018; Şahin, Ayar & Adıgüzel, 2014). Therefore, it can be concluded that administration of engineering design-based activities in the light of working in small groups might improve the creativity views of the students.

In social and cultural embeddedness aspect of NOE, the students' opinions about the influence between socio-cultural values of a society (religion, political and economic factors, worldview etc.) and engineering design solutions was developed positively after EDBI. Most of the students presented adequate and informed views of this aspect after the instruction because engineering design-based activities helped them experience to solve daily life problems by using their scientific knowledge. In the activities, engineering design solutions were given in scenarios. Firstly, they identified the problem or need, then they tried to find appropriate solutions by using their scientific knowledge and considering criteria and constraints (economic factors, time, accessibility of materials etc.). Moreover, the results of previous study showed that social injustices like local water pollution are analyzed and addressed by the students by using scientific principles (Dimick, 2012). The students integrated their scientific knowledge with the daily life problem to find solutions for water pollution, so social and cultural embeddedness of engineering was emphasized and improved with the daily life problem. Therefore, it can be concluded that experience to solve daily life problems based on engineering design-based activities might improve the social and cultural embeddedness views of the students.

Results of the study showed that less than half of the students held adequate and informed views of engineering design process (EDP) (29 %) and social aspects of engineering (37 %) of NOE after engineering design-based instruction. The same positive effect of EDBI was presented in these aspects of NOE in the study, but this effect did not have obtrusive percentage of students like previous aspects of NOE. All students held inadequate views for EDP aspect before EDBI, and percentage of students presenting adequate or informed views (29 %) increased after instruction. EDBI enabled the students to recognize EDP as a production process of tools and technologies to engage solutions for specific problems in real life context, and its steps ("finding a problem or need", "researching possible solutions", "choosing the best solution", and "building and testing the prototype"), in fact, some students supported their views with examples. For instance, some quotations were "EDP is about designing process having some steps.", "EDP has 4 steps; determining a problem, making research about the problem, finding the best solution for us, designing and testing. For example, we designed a building." etc. The results of previous studies also showed the positive effect of using engineering design process in science education on students' decision-making skills, scientific process skills and academic achievements (Guzey et al., 2016; English et al., 2017; English et al., 2013; English, 2018; Purzer et al., 2015; Roth, 2001; Fan & Yu, 2015; Bozkurt, 2014; Gencer, 2015; Yıldırım & Selvi, 2017); and the positive effect of STEM education on perceptions of classroom teacher candidates about EDP (Altaş, 2018). Therefore, it can be concluded that implementation of engineering design-based activities might improve the EDP views of the students.

In social aspects of engineering aspects of NOE, percentage of students presenting adequate or informed views (37 %) increased after instruction. Like EDP aspect, there was no obtrusive percentage of students, but there was increase in the students' views of this aspect. EDBI was student- centered and provided the students to work in small groups. During the activities, all students pretended like an engineer and discussed in group for materials, design etc., so they had effective social negotiation and improved the quality of their engineering design solutions with group members. The results of previous study showed that STEM activities based on daily life problems improved their motivation towards courses and creativity, and also their social life like career choices (Uğraş, 2018). Therefore, it can be concluded that working in small groups during engineering-design based activities might improve the students' social aspects of engineering aspect of NOE.

Results of the study showed that less than most of the students held adequate views of tentativeness (87 %), and subjectivity (62 %) aspects of NOE after engineering design-based instruction. The same positive effect of EDBI was presented in these aspects of NOE in the study, but this effect was also observed in comparison group receiving curriculum-based instruction (CBI). In both groups, the students' ideas about the flexibility of EDP steps and not being unique solution to an engineering design problem (tentativeness) were improved positively. Previous studies presented that participants improved their views of various NOE aspects after receiving an explicit instruction of NOE (Yeşilyurt et al.,2019; Deniz et al., 2017). Therefore, it can be concluded that emphasizing on tentativeness and subjectivity aspects of NOE might be limited during engineering-design based activities because of developing the activities based on EDP steps.

In summary, most of the participants generally held adequate and informed views of NOE aspects. The students taught with engineering design-based instruction (EDBI) showed development in their views of NOE aspects. However, in comparison group, the percentage of students' inadequate, adequate and informed views of demarcation aspect was close to each other, so there was no significant change for any view after curriculum-based instruction (CBI). Moreover, engineer drawings of the comparison group presented that most of the students drew an engineer with unknown gender, and there was no improvement in drawings in terms of themes (images of building/fixing, designing etc.) after CBI. In engineering design process (EDP) aspect, all students presented inadequate view after CBI because of not receiving EDBI which were developed based on EDP steps. Moreover, in social aspects of engineering aspect, there was an increase in inadequate views while there was a decrease in adequate views, and more than half of the students still presented inadequate views for this aspect of NOE after the instruction. In subjectivity, tentativeness social and cultural embeddedness aspects, improvement in adequate views of the students were presented, but percentage of inadequate view was still critically over. The results of creativity aspect of NOE showed that most of the students presented adequate views and there was no change in the percentage after CBI. The results of the present study showed that receiving curriculum-based instruction (CBI) did not have a significant improvement in the students' views about NOE aspects and also the number of the students showing inadequate views for various aspects was very critical. These results may be explained by the lack of an explicit instruction of NOE (Yeşilyurt et al., 2019; Deniz et al., 2017).

5.1.3. Attitudes Towards STEM

Research Question 3: What is the effect of engineering design-based instruction (EDBI) over curriculum-based instruction (CBI) on 7th grade students' attitudes towards STEM in Ankara?

In the present study, the effect of engineering design-based instruction on 7th grade students' attitudes towards STEM depending on four different sub-dimensions; mathematics, science, engineering and 21st century skills were assessed by M-STEM questionnaire.

Results of the study indicated that there was no statistically significant difference in students' attitudes towards STEM score taught with engineering design-based instruction and others taught with curriculum-based instruction after treatments. Previous studies showed the positive effect of STEM education on students' attitudes towards STEM or science (Yamak et al., 2014; Yasak, 2017; Baran et al., 2015; Guzey et al., 2016; Türk, 2018; Guzey et al., 2014; Mahoney, 2010). Students' attitudes towards STEM disciplines can be increased with the integration of technology and engineering in K-12 curriculum. Integration of engineering in curriculum increases students' academic achievement, 21st century skills, motivation towards learning science and their attitudes toward STEM (Guzey et al., 2016; Moore et al., 2015). However, the result of the present study was not consistent with previous researches. There was no significant effect of engineering design-based instruction on students' attitude towards STEM. This could be explained with the limited length of the study (3 weeks) on attitudinal change because attitudes are not easy to be changed. Therefore, in the present study, the length of the engineering design-based instruction (EDBI) might not be enough to improve or change the attitudes of the students towards STEM.

Moreover, results of four sub-dimensions (mathematics, science, engineering and 21^{st} century skills) were analyzed in terms of agreement percentages for items and change in mean scores among pre and post administrations in detail. The result of the mathematics and 21^{st} century skills sub-dimensions presented that EDBI affected the students' attitudes towards mathematics and 21^{st} century skills positively while others receiving curriculum based-instruction showed decrease in their attitudes towards them. For example, in mathematics sub-dimension, the students showed more agreement for choosing a career that uses math, being a student to do well in math, getting good grades in math, and being good at math. However, the participants receiving curriculum-based instruction presented decreasing agreement for these opinions. In addition, STEM Education is effective in developing individuals 21^{st} century skills, and they can adapt to the developments and innovations in the 21^{st} century (Uğraş, 2018; Khalil & Osman, 2017). For example, the students thought to be more confident about leading others to accomplish a goal, producing high quality work, respecting the differences of peers, helping peers, making changes when things do not go as planned, setting learning goals, and managing time wisely when working after engineering design-based instruction. However, mean score of attitudes towards 21^{st} century skills sub-dimension of STEM, and being confident about making changes when things do not go as planned, working well with students from different backgrounds, and including others' perspectives when making decisions were decreased after curriculum-based instruction. The results of previous studies showed that project-oriented problem-based learning (POPBL) in integrated STEM education program and after-school STEM activities increased the level of 21st century skills of the participants (Şahin, Ayar & Adıgüzel, 2014). The results of the mathematics and 21st century skills sub-dimensions provided to conclude that engineering design-based instruction might improve the attitudes towards mathematics and 21st century skills of the participants. To sum up, there was a positive effect of engineering design-based instruction on attitudes towards mathematics and 21st century skills sub-dimensions of STEM. This result is consistent with that integration of engineering in curriculum increases students' academic achievement, 21st century skills, motivation towards learning science and their attitudes toward STEM (Moore et al., 2015; Guzey et al., 2016).

The result of the third sub-dimension which is science showed that although there was no increase in mean score of attitudes towards science aspect of STEM, the students showed residual agreement in some items. Gülhan and Şahin (2016) showed the positive effects of STEM integration on students' attitudes towards the science, engineering and technology disciplines of STEM. This result might be resulted from the limited length of the study (3 weeks) on attitudinal change as mentioned before. Moreover, attitude may change from subject to subject (Kaynar, 2007). Recognizing the benefit of science in daily life is important for the interest in science and also learning science (Hoffman & Haussler, 1998). Therefore, in the present study, the length of the instruction and the students' lack of interest towards science might be factors about not changing attitudes towards science sub-dimension of STEM. Nevertheless, the students presented improvements in some items about attitudes towards science. For instance, the students agreed more to use science when getting out of school, to do advanced work in science after engineering design-based instruction, and to do a good job with science like most subjects. Nonetheless, students receiving curriculum-based instruction presented decreasing agreement about using science when getting out of school, being sure when doing science, having need science for future works, being important of science in life's work, considering a career in science, and knowing help of science to earn a living. Therefore, it can be concluded that engineering design-based instruction might have an effect in the improvement of some opinions about attitudes towards science of the participants.

The result of the last sub-dimension which is engineering indicated that in spite of unobtrusive decrease in mean score of attitudes towards engineering aspect of STEM, the students showed residual agreement in some items like in the science sub-dimension. The results of previous studies showed that the positive development on nature of engineering views of the students and teachers with explicit NOE instruction and engineering design experience (Yeşilyurt, Deniz, & Kaya, 2019; Deniz et al., 2017); the positive development on the perceptions of classroom teacher candidates about engineering with STEM education approach (Altaş, 2018); the effects of STEM applications integrated to science curriculum on female students' attitudes towards STEM and views of engineer and engineering (Yıldırım & Türk, 2018), the effect of design-based science education practices on the 7th grade students' academic achievement, their decision-making skills, and their perspectives and abilities on engineering discipline (Ercan, 2014). However, in the present study, there was no improvement in attitudes of the students towards engineering sub-dimension of STEM. This result might be resulted from the limited length of the instruction as mentioned before. Nevertheless, agreement percentages about improving things that people use every day by learning engineering, being interested in what makes machines work, being important of designing products or structures for future works, being curious about how electronics work, and knowing how to use math and science together to invent useful things were increased after engineering design-based instruction. However, mean score of attitudes towards engineering aspect of STEM, and agreement percentages about being interested in what makes machines work, being important of designing products or structures for future works, being curious about how electronics work, knowing how to use math and science together to invent useful things, using creativity and innovation in future works, and believing to be successful in a career in engineering decreased after curriculum based instruction. Therefore, it can be concluded that engineering design-based instruction might have an effect in the improvement of attitudes towards engineering of the participants.

5.2. Conclusions

Engineering is a part of the Next Generation Science Standards (NGSS Lead States, 2013). Teachers should explicitly introduce NOE ideas to their students and students should have an opportunity to present their experience during engineering design process (Yeşilyurt et al., 2019) similar to the positive effect of explicit NOS instruction (Abd-El-Khalick & Lederman, 2010). In the present study, significant difference was presented in NOE views between the students receiving engineering design-based instruction and others receiving curriculum-based instruction. Moreover, engineering design-based instruction improved various aspects (demarcation criteria, creativity, social and cultural embeddedness, engineering design process (EDP), social aspects of engineering) of the students more than the improvement of curriculum-based instruction. The results of the present study showed that the students' views on demarcation criteria, engineering design process, social and cultural embeddedness, social aspects of engineering, creativity aspects of NOE receiving engineering design-based instruction were improved positively. As the results of the study showed that receiving curriculum-based instruction (CBI) did not have a significant improvement in students' views of NOE aspects and also the number of the students showing inadequate view for various aspects was very critical. Therefore, students' experiences in engineering design challenges can help them to have more sophisticated NOE views.

The results of the study showed that there was no significant effect of engineering design-based instruction on students' attitude towards STEM. However, the students showed improvements in mathematics and 21st century skills, but not showed improvement in engineering and science disciplines. This could be explained with the limited length of the study (3 weeks) on attitudinal change because attitudes are not easy to be changed. Moreover, attitude may change from subject to subject (Kaynar, 2007). In the present study, the length of the instruction and the students' lack of interest towards science and engineering might be factors about not changing attitudes towards science and engineering sub-dimensions of STEM.

5.3. Implications and Recommendations for Further Studies

In this study, the effects of engineering design-based instruction on 7th grade students' nature of engineering views and attitudes towards STEM was investigated. In the science education, nature of science (NOS) is a major research agenda and a crucial component of scientific literacy. NOS is described as a way of knowing, the epistemology of science, and the values and beliefs which are constitutional issues for the development of scientific knowledge (Lederman, 1992). By considering the similarity between nature of science (NOS) and nature of engineering (NOE), the NOE framework was developed by adapting NOS research framework for the purpose of assessing the participants' NOE views (Deniz et al., 2017) because engineering and engineering design were emphasized in Next Generation Science Standards (NGSS Lead States, 2013) and Turkish Science Curricula (MEB, 2017; MEB; 2018). Like parallelism of NOE and NOS conceptualizations in NGSS, all NOE aspects are similar to the NOS aspects except engineering design process aspect of NOE. However, researches exploring the participants NOE views area still rare because of being a new research area in science education, so there is a need for studies assessing the NOE views of the participants. Moreover, integration of engineering in curriculum increases students' academic achievement, 21st century skills, motivation towards science learning and attitudes towards STEM (Moore et al., 2015). Therefore, this study was designed to assess the changes on NOE views and attitudes towards STEM of the 7th grade students after participating engineering design-based instruction.

In the present study, significant difference was presented in NOE views between the students receiving engineering design-based instruction and others receiving curriculum-based instruction. Engineering design-based instruction improved various aspects of the students more than the improvement of curriculum-based instruction. However, students' views on tentativeness and subjectivity aspects of NOE did not show obstrusive development after engineering design-based instruction. This result might be explained with limited emphasize on these aspects of NOE through engineering design-based instruction. On the other hand, significant effect was not presented in attitudes towards STEM between the students receiving engineering design-based instruction and others receiving curriculum-based instruction. The students showed improvements in mathematics and 21st century skills, but not showed improvement in engineering and science disciplines. This result could be explained with the limited length of the study (3 weeks) on attitudinal change because attitudes are not easy to be changed. Therefore, much should be done with long-term engineering design-based instruction to enhance students' attitudes towards STEM. Therefore, this finding might be useful for planning NOE instruction for science teachers and science teacher educators. The process of the instruction might be extended, and all aspects of NOE might be emphasized explicitly. Moreover, working with a mechanical engineer improved the students' engineering view positively, so The Ministry of Education might encourage science teachers or educators about inviting or working with engineers through their science lectures.

There also might be some other factors interfering with the learning process. The engineering design-based instruction might be taught explicitly in experimental group while it might be taught implicitly in comparison group in future studies because it might be more effective to analyze the effect of engineering design-based instruction among groups. Moreover, the personal characteristics of the students might be considered in future researches, so the relationships between NOE views and personal characteristics might be determined. For instance, NOE views and all other variables (e.g., gender, academic background, motivation, learning styles etc.) can be measured in both before and after engineering design-based instruction, so it might be determined whether or not a specific variable influences students' NOE views. Besides, the students' attitudes towards STEM did not change significantly after engineering design-based instruction. This also might be caused from the students' interest on the unit of the subject (Force and Energy unit), so the unit taught with engineering design-based instruction might be changed with other subjects to assess students' attitudes towards STEM in future researches. Moreover, students' attitudes towards STEM might be analyzed by considering STEM identity and STEM self-efficacy in future studies.

Besides, the sample size is an important factor in quantitative studies for generalizability of the results. Therefore, much more information about attitudes towards STEM could be gathered by increasing sample size of the size. Moreover, in collecting qualitative data of study, interview was not used to assess the students' NOE views. Therefore, interview may be conducted to explain the changes in NOE aspects after engineering design-based instruction in future researches.

In conclusion, with the help of the present study, previous and future studies, better ways to improve learners' NOE views and attitudes towards stem might be found. These studies might be useful for science teachers, pre-service science teachers, and science teacher educators while planning NOE instruction.

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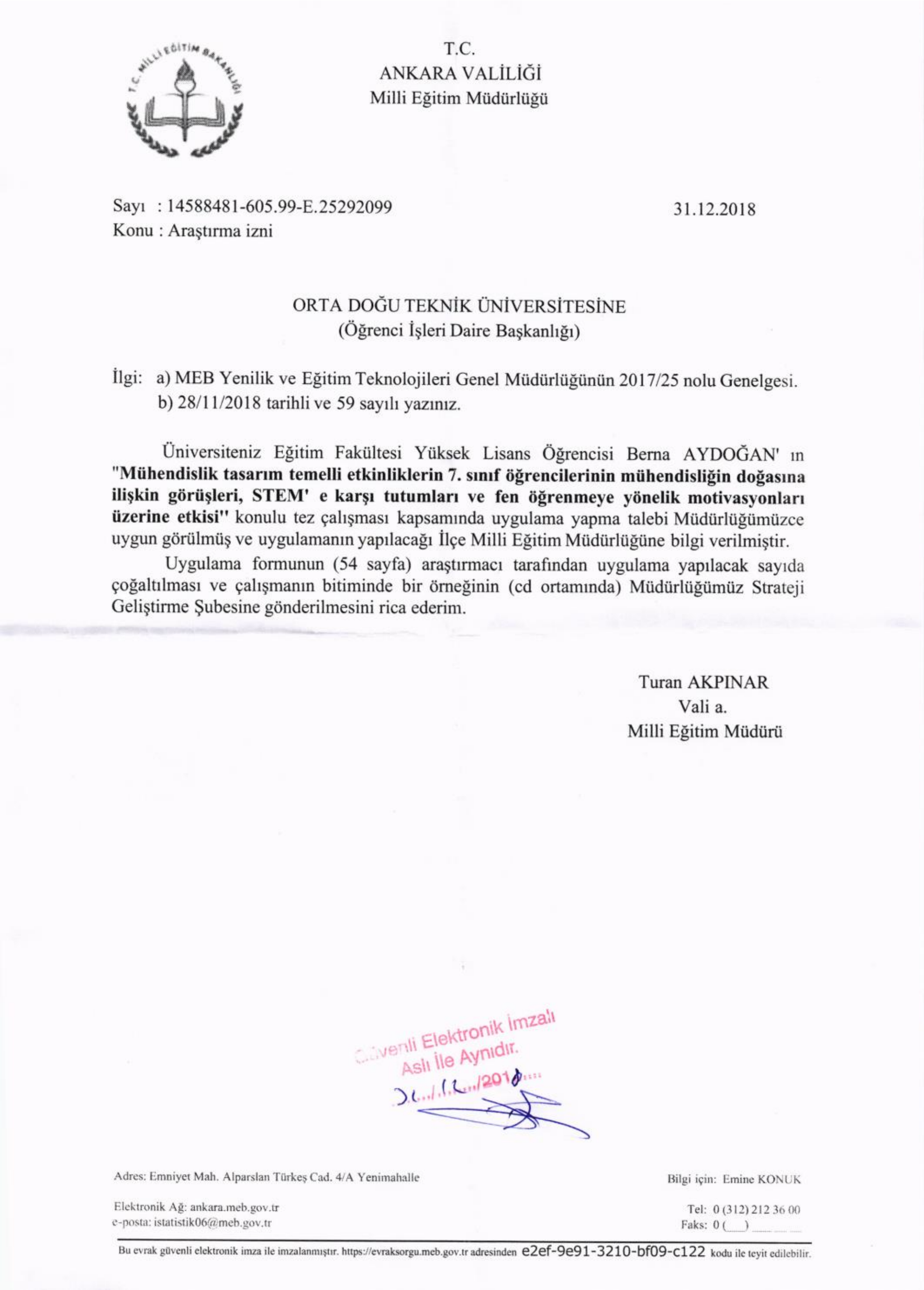
APPENDICES

APPENDIX-A



T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

Sayı : 14588481-605.99-E.25292099 — 31.12.2018
Konu : Araştırma izni

ORTA DOĞU TEKNİK ÜNİVERSİTESİNE
(Öğrenci İşleri Daire Başkanlığı)

İlgi: a) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2017/25 nolu Genelgesi.
b) 28/11/2018 tarihli ve 59 sayılı yazınız.

Üniversiteniz Eğitim Fakültesi Yüksek Lisans Öğrencisi Berna AYDOĞAN' ın **"Mühendislik tasarım temelli etkinliklerin 7. sınıf öğrencilerinin mühendisliğin doğasına ilişkin görüşleri, STEM' e karşı tutumları ve fen öğrenmeye yönelik motivasyonları üzerine etkisi"** konulu tez çalışması kapsamında uygulama yapma talebi Müdürlüğümüzce uygun görülmüş ve uygulamanın yapılacağı İlçe Milli Eğitim Müdürlüğüne bilgi verilmiştir.

Uygulama formunun (54 sayfa) araştırmacı tarafından uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde bir örneğinin (cd ortamında) Müdürlüğümüz Strateji Geliştirme Şubesine gönderilmesini rica ederim.

Turan AKPINAR
Vali a.
Milli Eğitim Müdürü

Güvenli Elektronik İmzalı
Aslı İle Aynıdır.
31/12/2018

Adres: Emniyet Mah. Alparslan Türkeş Cad. 4/A Yenimahalle
Elektronik Ağ: ankara.meb.gov.tr
e-posta: istatistik06@meb.gov.tr

Bilgi için: Emine KONUK
Tel: 0 (312) 212 36 00
Faks: 0 (___)

Bu evrak güvenli elektronik imza ile imzalanmıştır. https://evraksorgu.meb.gov.tr adresinden e2ef-9e91-3210-bf09-c122 kodu ile teyit edilebilir.

APPENDIX-B

MÜHENDİSLİĞİN DOĞASINA YÖNELİK GÖRÜŞLER; İLKÖĞRETİM VERSİYONU (MDYG)

Ad Soyad:______________________________

Sınıf Seviyesi:___________________________

Tarih:__________________________________

Açıklamalar

- *Lütfen aşağıdaki her soruyu cevaplayınız. Soruları cevaplamak için her soru altında bulunan bölümü ve sayfanun arka yüzünü kullanabilirsiniz.*
- *Aşağıdaki bazı sorular birden fazla bölüm içermektedir, bu nedenle lütfen her bölüm için cevap verdiğinizden emin olunuz.*
- ***Bu bir test ya da sınav değildir, ve notlandırılmayacaktır.** Aşağıdaki her sorunun "doğru" ya da "yanlış" cevabı yoktur, sadece her soru hakkındaki fikir ve görüşleriniz ile ilginilmektedir.*
- *İhtiyaç duyulursa fikirlerinizi açıklamak adına çizim yapabilirsiniz.*

1. Büyüdüğün zaman ne tür bir meslek/meslekler sahibi olmak istersin?

2. Mühendislik nedir? Mühendisler ne iş yapar?

3. Büyüyünce mühendis olmayı hiç düşündün mü? Cevabın evet ise “Evet”, hayır is “Hayır” yanıtını işaretleyerek lütfen sebebini açıkla.

- ❑ *Evet, mühendis olmayı düşünmemin sebebi*_________________

- ❑ *Hayır, mühendis olmayı düşünmememin sebebi*_________________

4. Lütfen bir mühendisi çalışma ortamında hayal edin ve hayalinizdeki bu mühendisi aşağıdaki kutuya çizin

Lütfen kısa cümlelerle çizmiş olduğun mühensis hakkında bilgi ver.

- *Çizdiğiniz mühendisin çalışma ortamı nasıl?*

- *Çizdiğiniz mühendis hangi alanda çalışıyor?*

- *Çizdiğiniz mühendis çizimde ne yapıyor?*

5. (a) Öğrenmiş ya da öğrenmekte olduğun diğer meslekler neler?

   (b) Mühendislik diğer mesleklerden hangi açıdan farklıdır?

6. Daha önce “mühendislik tasarım süreci” ifadesini duydun mu?

   ❑ *Evet*______

   ❑ *Hayır*______

   Cevabın “Evet” ise, “mühendislik tasarım süreci” sana ne/neler ifade ediyor?

7. Mühendislik her zaman insanların problemleri için çözüm bulma arayışındadır. Mühendislerin ürettiği bu çözümlerin gelecekte değişeceğini düşünüyor musun?

8. Mühendisler çalışma ortamında yaratıcılık ve hayal güçlerini kullanırlar mı?

❑ *Evet, kullanırlar çünkü*____

❑ *Hayır, kullanmazlar çünkü*_______________________________________

9. "Orta Amerika ve Karayipler'de coğrafi konumlarından dolayı çok şiddetli kasırga ya da rüzgarlar meydana gelmektedir. Bu nedenle birçok bina büyük hasar görmekte hatta yıkılmaktadır. Bu nedenle binaların yıkılmaması ya da daha az hasar görmesi için daha sağlam yapı ve tasarıma ihtiyaç vardır."

Karşılaşılan bu sorunu çözmek için birden fazla mühendisten "Kasırga Kulesi" tasarlamaları isteniyor. Tasarım süresi sonunda her mühendisin tasarımları değerlendirildiğinde “en iyi” ve "tek tip" tasarım var mıdır?

❑ *Evet, çünkü*____

❑ *Hayır, çünkü*____

10. Mühendislik tasarım çözümleri (örneğin; meşrubat içeceği kıracağı, köprüler, bilgisayarlar vs.) nasıl hayatımızı etkiler?

11. Mühendisler nasıl çalışırlar? Yalnız olarak mı yoksa grup halinde mi?

APPENDIX-C

DESCRIPTIONS OF NATURE OF ENGINEERING (NOE) ASPECTS

NOE Aspect	Description
Demarcation criteria (What is engineering? What makes engineering different from other disciplines?)	Engineering is systematically engaging in the practice of design to achieve solutions for specific problems. Engineers apply their understanding of the natural world (scientific knowledge) to design solutions for real world problems. This endeavor results in new technologies. In the K-12 context, “science” is generally taken to mean the traditional natural sciences: physics, chemistry, biology, and (more recently) earth, space, and environmental sciences… We use the term “engineering” in a very broad sense to mean any engagement in a systematic practice of design achieve solutions to particular human problems. Likewise, we broadly use the term “technology to include all types of human-made systems and processes-not in the limited sense often in schools that equates technology with modern computational and communications devices. Technologies result when engineers apply their understanding of natural world and of human behavior to design ways to satisfy human needs and wants. (NRC, 2012, pp. 11-12)
Engineering design process	The core idea of engineering design includes three component ideas (NGSS Lead States, 2013): Define, Design, and Optimize

A. Define: Defining and delimiting engineering problems involves stating the problem to be solved as clearly as possible in terms of criteria for success and constraints or limits.
B. Design: Designing solutions to engineering problems begin with generating a number of possible solutions. These potential solutions are then evaluated to assess which ones best meet the criteria and constraints of the problem.
C. Optimize: Optimizing the design solution involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important.

Empirical basis	Engineers optimize their design solutions and compare alternative solutions based on evidence obtained from test data. They use assumptions to produce simplified models that does not contain the variables that the problem are insensitive to.
Tentativeness	Phases of engineering design process do not always follow in order, any more than do the “steps” of scientific inquiry. At any phase, a problem solver can redefine the problem or generate new solutions to replace an idea that is just not working out.
Creativity	Creativity and imagination of engineers play a major role during the engineering design process. The role of creativity and imagination is not limited to any specific phase of the engineering design process.

Subjectivity	There is no unique solution to an engineering design problem. While there can be many solutions to the same problem, some of these solutions may be more suited to meet the criteria and constraints of the problem.
Social aspects of engineering	Engineering is not a solitary pursuit. Engineering design solutions are constructed through social negotiation. Despite their individual differences, members of an engineering community share common understandings, traditions, and values. This social dimension enhances the quality of engineering design solutions.
Social and cultural embeddedness	Engineering is a human activity. There is a continued interaction between engineering and society. Sociocultural factors influence the engineering design process, and in turn, engineering influences the society. These social and cultural factors include social composition, religion, worldview, political, and economic factors.

A 5-point scale

13. No answer, incomprehensible or irrelevant answer, or an answer could not be categorized = 0 points;
14. An answer that is not aligned with the description of NOE aspect = 1 point;
15. An answer that is partially aligned with the description of NOE aspect = 2 points;
16. An answer that is fully aligned with the description of NOE aspect = 3 points;
17. An answer that is fully aligned with the description of NOE aspect. The view is well-articulated and/supported with relevant example(s) = 4 points.

APPENDIX-D

ORTAOKUL ÖĞRENCİLERİNİN STEM'E (S-STEM) KARŞI TUTUMU

Ad Soyad:

Sınıf:

Sevgili öğrenciler,

Bu ölçek sizin Fen Bilimleri dersine yönelik STEM'e ilişkin düşüncelerinizi belirlemek amacıyla geliştirilmiştir. Burada belirteceğiniz görüşler yalnızca araştırma amacıyla kullanılacak ve sonuçlar tüm grubun yanıtları göz önüne alınarak değerlendirilecektir. Bu araştırmanın güvenirliği için gerçek düşüncelerinizi belirtmeniz özel bir önem taşımaktadır. **Lütfen hiçbir maddeyi boş bırakmayınız ve her biri için tek yanıt veriniz. Vereceğiniz bu yanıtlar bilimsel bir çalışma için kullanılacak ve başka kişiler ile paylaşılmayacaktır.**
Bu çalışmaya yaptığınız katkılardan dolayı teşekkür ederim.

Yönerge: Aşağıdaki sayfalarda ifadelere dair listeler bulunmaktadır. Lütfen kendinizi her bir ifade ile ilgili nasıl hissettiğinizi cevap kağıdı üzerinde işaretleyerek belirtin.
Örneğin:

Örnek 1:	**Kesinlikle Katılmıyorum**	**Katılmıyorum**	**Kararsızım**	**Katılıyorum**	**Kesinlikle Katılıyorum**
Mühendisliği seviyorum.	○	○	○	○	○

Cümleyi okuyunca buna katılıp katılmadığınızı bileceksiniz. Bu ifadeye ne ölçüde katıldığınızı tanımlayan yuvarlağı işaretleyin. Bazı ifadeler birbirine çok benziyor olsa da lütfen bütün ifadeler için ilgili cevabı işaretleyin. Bu seçeneklerin işaretlenmesi zaman açısından ölçülmemektedir; hızlı ancak dikkatli bir şekilde çalışın.

Hiçbir şekilde "yanlış" ya da "doğru" cevap seçenekleri söz konusu değildir! Tek doğru yanıt sizin için doğru olan yanıttır. Mümkün olduğu noktada sizin başınız gelmiş olabilecek durumların sizin tercihte bulunmanıza yardım etmesine izin verin.
Lütfen her soru için bir cevabı işaretleyin.

MATEMATİK

	Kesinlikle Katılmıyorum	**Katılmıyorum**	**Kararsızım**	**Katılıyorum**	**Kesinlikle Katılıyorum**
1. Matematik benim en kötü olduğum derstir.	○	○	○	○	○
2. Matematiğin kullanıldığı bir kariyeri seçmeyi düşünebilirim.	○	○	○	○	○
3. Matematik benim için zor.	○	○	○	○	○
4. Matematikte başarılı olabilecek bir öğrenciyim.	○	○	○	○	○
5. Birçok dersle başa çıkabilirim ancak matematikle başa çıkamıyorum.	○	○	○	○	○
6. Matematik konusunda ileri seviyede çalışmalar yapabileceğimden eminim.	○	○	○	○	○
7. Matematikte iyi notlar alabilirim.	○	○	○	○	○
8. Matematikte iyiyim.	○	○	○	○	○

FEN					
	Kesinlikle Katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Kesinlikle Katılıyorum
1. Fen ile ilgilenirken kendimden emin davranıyorum.	○	○	○	○	○
2. Fen üzerine bir kariyer yapmayı düşünebilirim.	○	○	○	○	○
3. Okuldan mezun olduğumda fen'i kullanmayı umut ediyorum.	○	○	○	○	○
4. Fen konusunda bilgili olmam benim hayatımı kazanmama yardım edecek.	○	○	○	○	○
5. Gelecekteki çalışmalarım için fene ihtiyacım olacak.	○	○	○	○	○
6. Fen konusunda başarılı olabileceğimi biliyorum.	○	○	○	○	○
7. Hayatımdaki çalışmalarda, fen benim için önemli olacak.	○	○	○	○	○
8. Birçok dersle başa çıkabilirim ancak fenle başa çıkamıyorum.	○	○	○	○	○
9. Fen konusunda ileri seviyede çalışmalar yapabileceğimden eminim.	○	○	○	○	○

MÜHENDİSLİK					
	Kesinlikle Katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Kesinlikle Katılıyorum
1. Yeni ürünlerin üretildiğini hayal etmek hoşuma gidiyor.	○	○	○	○	○
2. Mühendisliği öğrenirsem, insanların günlük yaşamlarında kullandığı şeyleri geliştirebilirim.	○	○	○	○	○
3. Bir şeyleri oluşturmak ve onları tamir etmekte iyiyim.	○	○	○	○	○
4. Makinelerin nasıl çalıştığı ile ilgiliyim.	○	○	○	○	○
5. Ürünler veya yapılar tasarlamak gelecekteki çalışmalarım için önemli olacak.	○	○	○	○	○
6. Elektronik eşyaların nasıl çalıştığı konusunda meraklıyım.	○	○	○	○	○
7. Yaratıcılık ve yeniliği gelecekteki çalışmalarında kullanmak isterim.	○	○	○	○	○
8. Matematik ve Fen'i birlikte nasıl kullanacağımı bilmek bana kullanışlı şeyler icat etme şansı tanıyacak.	○	○	○	○	○
9. Mühendislik konusunda başarılı bir kariyere sahip olabileceğime inanıyorum	○	○	○	○	○

21. YÜZYILIN YETENEKLERİ					
	Kesinlikle Katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Kesinlikle Katılıyorum
1. Diğer bireylere bir hedefe ulaşmalarında liderlik edebileceğim konusunda kendime güveniyorum.	○	○	○	○	○
2. Diğer bireyleri ellerinden gelenin en iyisini yapmaları için cesaretlendirebileceğime inanıyorum.	○	○	○	○	○
3. Yüksek kalitede çalışmalar yapabileceğimden eminim.	○	○	○	○	○
4. Akranlarımın farklılıklarına karşı saygılı davranacağımdan eminim.	○	○	○	○	○
5. Akranlarıma yardım edebileceğime eminim.	○	○	○	○	○
6. Karar verirken başkalarının görüşlerini göz önüne alacağımdan eminim	○	○	○	○	○
7. İşler planlandığı gibi gitmediğinde değişiklikler yapabileceğimden eminim.	○	○	○	○	○
8. Kendi öğrenme hedeflerimi belirleyebileceğime inanıyorum.	○	○	○	○	○
9. Kendi başıma çalışırken zamanımı akıllıca yönetebileceğimden eminim.	○	○	○	○	○
10. Yapmam gereken görevler olduğunda hangilerinin önce yapılmaları gerektiğini seçebilirim.	○	○	○	○	○
11. Farklı altyapılara sahip olan öğrencilerle iyi bir şekilde çalışabileceğimden eminim.	○	○	○	○	○

APPENDIX-E

- İnsanların her türlü ihtiyacını karşılamaya dayalı çeşitli çözümler üreten, teknik ve sosyal alanlarda uzmanlaşmış ve belli bir eğitim görmüş kimseye **mühendis** denir.
- Bilim insanlarının ürettiği teorik bilgiyi pratik bilgiye dönüştürür.
- Matematik ve geometri temeline yerleşir.

Mühendislik ürünleri nelerdir?

Mühendis olmak ister misin?

Mühendis olmak;

- Düşünmeyi
- Yaratıcı olmayı
- Olaylara sistematik olarak bakmayı
- Parçaları birleştirip bütünü görebilmeyi
- Neden sonuç ilişkilerini kurabilmeyi
- Bakış açısını değiştirmeyi

Uçak Mühendisliği (Havacılık ve Uzay Mühendisliği)

Kimya ve Biyoloji Mühendisliği

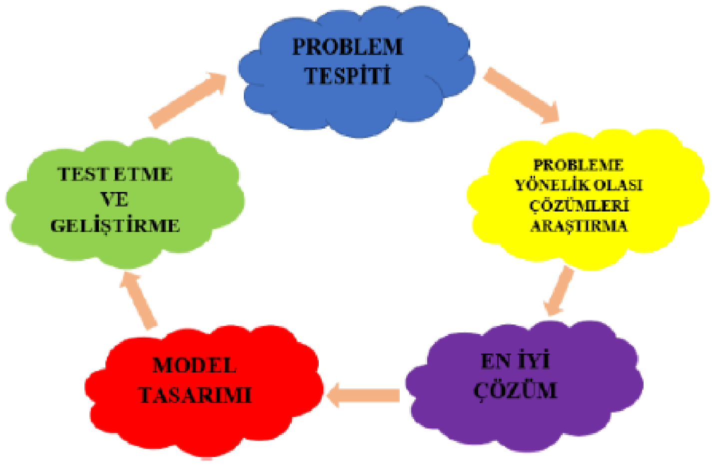
İnşaat Mühendisliği

Çevre Mühendisliği

Makine Mühendisliği

Biyomedikal Mühendisliği

Mühendislik Tasarım Süreci



<u>1. Problem Tespiti:</u>

Yaşamlarındaki ya da çevrelerindeki sorunları tespit eder ve listelerler.

Değiştirmeyi, geliştirmeyi , farklılaştırmayı düşündükleriniz ve çözüm bekleyen sorunlarınız nelerdir ?

<u>2. Probleme Yönelik Olası Çözümleri Araştırma</u>

Daha önceden yapılmış olan ve benzer sorunlar için bulunmuş çözümleri ve tasarımları araştırırlar.

3. En İyi Çözüm

Bulunan çözümler arasından uygun çözüm seçilerek nasıl gerçekleştireceği ve kullanılacak araç - gereç ve malzemeleri, yöntem teknikleri belirlerler.

Araştırma sonuçları dikkate alarak tasarımın yapım resmini çizerler.

4. Model Tasarımı

En iyi çözüm ya da tasarıma yönelik yapım aşamasıdır.

Kullanılması uygun görülen malzemeler ile planlanan tasarım üç boyutlu şekilde yapılır.

5. Test Etme ve Geliştirme

Yapım aşaması bitmiş olan tasarımı test ederler.

Sorun çözümlendi mi?, İhtiyacı karşılıyor mu?, Benzer ürünlere göre zayıf ve üstün yanları var mı ?, Hangi özelliklerin değiştirilmeye ihtiyacı var?

Bir şirket bazı personellerini iş toplantıları için sürekli yurtdışı seyahatine göndermektedir. Fakat son zamanlarda hem uçak bileti fiyatlarından hem de biletlerin çabuk tükenmesinden dolayı ciddi sorunlar yaşamaktadır.

1. Problem Tespiti

Uçak bileti fiyatlarındaki artış ve uçaklardaki doluluk oranlarından dolayı sıkıntı yaşayan personeller

2. Probleme Yönelik Olası Çözümleri Araştırma

- Uçak biletleri belli bir süre öncesinde satın alınabilir.
- Belli bir havayolu şirketi ile anlaşma imzalanabilir.
- ......
- Hem ekonomik hem de zamandan tasarruf sağlayan bir uçak tasarlanabilir.

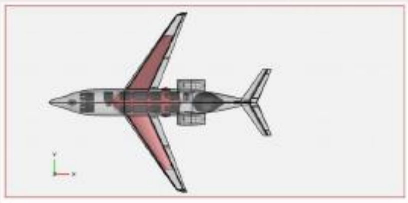
3. En İyi Çözüm

Hem ekonomik hem de zamandan tasarruf sağlayan bir uçak tasarlanabilir.

- **Hangi alanda çalışan mühendise ihtiyaç olabilir?**

Uçak Mühendisliği

4. Model Tasarımı



Kılıç Balığı

5. Test Etme ve Geliştirme

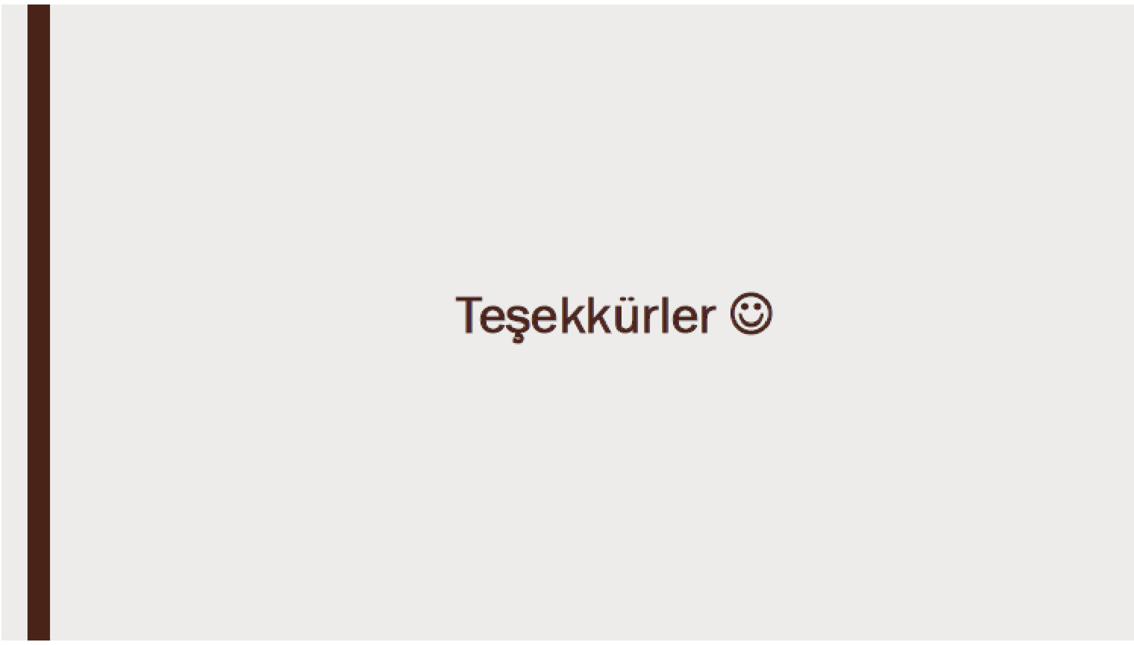
Mühendislik tasarım süreci basamakları sıralı mıdır yoksa değişebilir mi?

- Mühendislik tasarım süreci basamakları belirli bir sıra halinde değildir.
- Herhangi bir basamakta problemi yeniden belirleyebilir ve yeni çözümler üretebilir.

Sizce köprüler neden farklı tasarımlara sahiptir?

Sizce MR (Manyetik Rezonans) cihazları neden farklı tasarımlara sahiptir?

- Mühendislik tasarım süreci basamaklarının her birinde, mühendislerin yaratıcılık ve hayal güçleri büyük rol oynar.
- Problemler için üretilen çözüm ve tasarımlar «tek» ve «en iyi» şeklinde belirtilmemeli.
- Belirlenen problem için birden fazla çözüm ve tasarım olabilir, fakat bu çözümler arasından bazıları problemin sınırlılık ve kriterleri nedeniyle daha uygun olabilir.


Teşekkürler ☺

APPENDIX-F

STEM ANALYSIS CRITERIA

The Activity	Yes	Partially	No
1. Does the activity include a daily life prolem? If yes;	X		
• Is it an interesting problem for the students?	X		
• Is it familiar and understandable for the students?	X		
2. Does the activity include integration of one or more than one disciplines of STEM? If yes;	X		
• Does it include engineering design homework?		X	
• Does it make connection with mathematics concepts?		X	
• Is it appropriate for technology use?	X		
3. Is the activity student-centered? If yes;	X		
• Does it give an opportunity to the students about making their own searches?	X		
• Does it enable the students to present scientific questions when the students design?	X		
• Does it avoid direction (choosing materials, design process etc.) when the students design?	X		
4. Does the activity have the characteristics of project, problem and inquiry-based learning approaches? If yes;	X		
• Does it provide an opportunity to the students to study on a problem or project?	X		
• Does it provide an opportunity to the students to hypothesize and to design a project or process based on their hypothesis?	X		
• Does it allow the students for creativity, thinking and inquiry skill, cooperative learning, designing and innovation?	X		
• Do the students present their designs (a project or process) by verbally or a poster?	X		
5. Does the activity provide an opportunity to the students to work in small groups and group communication?	X		
6. Does the activity provide an opportunity to the students to redesign their designs?	X		
• Does it ask the students what and why they change in redesign step?	X		

7. Does the activity provide an opportunity to evaluate the design based on criteria (cost, time, availability of materials etc.)? If yes;	X
• Does it present a rubric to evaluate the design in intergroup?	X
• Did the criteria in the rubric be presented to the students at the beginning of the activity?	X

APPENDIX-G

"KULE TASARIMI" DERS PLANI

Sınıf Seviyesi: 7. Sınıf

Ünite: 7.3 Kuvvet ve Enerji / Fiziksel Olaylar

Konu: 7.3.2. Kuvvet, İş ve Enerji İlişkisi

Ön Bilgiler: Öğrenciler;

- Kuvvetin tanımı ve birimi *(F.4.3.1. Kuvvetin Cisimler Üzerindeki Etkileri/ F.5.3.1. Kuvvetin Ölçülmesi)*
- Sürtünme Kuvveti *(F.5.3.2. Sürtünme Kuvveti)*
- Kütle ve Ağırlık *(F.7.3.1. Kütle ve Ağırlık İlişkisi)*
- Kinetik enerji, çekim potansiyel enerjisi, esneklik potansiyel enerjisi *(F.7.3.2. Kuvvet, İş ve Enerji İlişkisi)*

Kazanımlar

F.7.3.2.1. Enerjiyi iş kavramı ile ilişkilendirerek, kinetik ve potansiyel enerji olarak sınıflandırır.

F.7.3.2.2. Kinetik ve potansiyel enerji ile ilişkilendiren probleme (topun yere en büyük hızla ulaşmasını sağlayan en sağlam ve en az maliyetli kule inşa etmek) yönelik üç boyutlu bir proje tasarlar.

F.7.3.2.3. Mühendisliğin doğası yönlerini (mühendislik tasarım süreci, mühendislik kriterleri (demarcation criteria), yaratıcılık (creativity), geçicilik (tentativeness), öznellik (subjectivity)) açıklar.

Kullanılacak Materyal ve Teknoloji Destekleri

- *Bilgisayar ve projeksiyon cihazı, ya da akıllı tahta :* Konu ile ilgili hazırlanmış slaytı öğrencilere göstererek dersin takibini kolaylaştırmak ve proje tasarımı sırasında öğrencilere zaman yönetiminde kolaylık sağlayan zamanlayıcıyı gösterebilmek için kullanılır.
- *Konu ile ilgili hazırlanmış slayt (https://prezi.com/pui_cnzbd8wd/kasirga-kulesi-tasarimi/):* Hem öğretmen hem de öğrenciler için ders takibini kolaylaştıran slayt, konu ile ilgili bir problem, konu ile ilgili video, proje tasarımı için gerekli materyallerin listesi, zamanlayıcı ve olası projelerin görsellerini içermektedir.
- *Simülasyon (https://www.fenehli.com/enerji-donusumleri-simulasyonlari/) :* Öğretmen, kinetik enerji ve potansiyel enerji, enerji dönüşümleri ve enerjinin korunumu durumlarını göstermek amacıyla akıllı tahta yardımı ile bir simülasyon açar.
- *Zamanlayıcı(https://tr.piliapp.com/timer/countdown/#pause=2699545,all=00:45:00):* Proje tasarımı sırasında öğrenciler için süre yönetimi kolaylığı sağlar.
- *Aktivite Kağıdı (EK – 1):* Aktivite kağıdı, proje tasarımı sırasında öğrencilere dağıtılarak hedeflenmiş olan mühendisliğin doğası yönlerini takip etmeyi kolaylaştırır. Aktivite kağıdında "mühendislik tasarımı süreci" adımlarını (problem tespiti, probleme yönelik olası çözümleri araştırma, en iyi çözümü bulma, ve modeli tasarlama, test etme ve geliştirme) ve diğer mühendisliğin doğası yönlerini (mühendislik kriterleri (demarcation criteria), yaratıcılık (creativity), geçicilik (tentativeness), öznellik (subjectivity)) kapsayan sorular içermektedir.

ÖĞRETİM SÜRECİ

Öğretmen derse öğrencilerin ön bilgilerini hatırlatarak başlar. Kuvvetin tanımı ve birimi; kütlenin tanımı ve birimi; ağırlığın tanımı ve birimi; ağırlığın da bir kuvvet olduğu; kütle ve ağırlık kavramlarının arasındaki farklar öğrenciler ile soru-cevap yaparak ön bilgileri hatırlamaları hedeflenir. Hatırlanması beklenen kısa bilgiler öğrencilerden alındıktan sonra öğretmen tarafından hazırlanmış olan slaytta da verilir.

Öğrencilerin ön bilgileri alındıktan sonra öğretmen, tatile gittikleri zaman havuza atlama tahtasından kendilerine havuza bırakıp bırakmadıklarını sorar. Ağırlığı daha fazla olan ya da daha yüksek havuz tahtasından atlayan bir arkadaşı ile havuzdaki dalma derinliklerinde bir fark olup olmayacağı sorulur. Öğrencilerin fikirleri alındıktan sonra, potansiyel ve kinetik enerjiye giriş yapabilmek için bir video izletilir.

Daha sonra öğretmen, akıllı tahtada potansiyel ve kinetik enerji ile ilgili bir simülasyon açar. Öğretmen ilk olarak kendisi gösterir, sonrasında sınıftan bir öğrencinin yardımı ile sınıfça alıştırma yapılır. Bu simülasyonda öğrenciler kinetik ve potansiyel enerji türlerini gözlemleyerek kavrar.

Fiziksel anlamda yapılan işin değeri, uygulanan kuvvetin şiddetine ve cismin aldığı yolun büyüklüğüne bağlı olduğu açıklanır. Uygulanan kuvvetin şiddeti ve cismin aldığı yol arttığında fiziksel anlamda yapılan işin değeri de artar. Yani işin değeri, uygulanan kuvvetin şiddeti ve cismin aldığı yol ile doğru orantılıdır. Uluslararası birim sistemine (SI) göre, işin birimi Joule (J)'dür.

Öğrencilere sabit bir duvara kuvvet uygulayan öğrencinin, fiziksel anlamda iş yapıp yapmadığı sorulur. Öğrencilerin tahminleri alındıktan sonra, öğrencinin iş yapmış sayılmadığı açıklanır. Çünkü duvara bir kuvvet uygulamasına karşın duvar yol almaz.

Öğrencilere yerde duran sırt çantasını masasının üzerine çıkaran öğrencinin, fiziksel anlamda iş yapıp yapmadığı sorulur. Öğrencilerin tahminleri alındıktan sonra, öğrencinin iş yapmış sayıldığı açıklanır. Çünkü öğrencinin çantaya, masanın üzerine çıkarmak için uyguladığı kuvvet ile çantanın aldığı yol dikey doğrultudadır.

Öğrencilerden de hem kinetik hem de potansiyel enerji türlerine günlük hayattan örnekler alındıktan sonra, iş yaparken enerji harcadığımız ve enerjinin iş yapabilme yeteneği olduğu açıklanır. İki çeşit enerji çeşidi olduğu ve bunların kinetik ve potansiyel enerji oldukları açıklanır *(Kazanım 7.3.2.1.).* Aynı zamanda potansiyel enerjinin de kendi içinde çekim potansiyel enerjisi ve esneklik potansiyel enerjisi olarak iki çeşidi olduğu açıklanır.

> **Kinetik Enerji:** Cisimlerin süratlerinden dolayı sahip olduğu enerjidir. Bu sebeple kinetik enerjiye hareket enerjisi de denir. Örneğin; koştuğumuzda, yürüdüğümüzde, hareket hâlinde olduğumuzda vb. Bir cismin sahip olduğu kinetik enerji, o cismin kütlesine ve süratine bağlıdır. Cismin kütlesi ve sürati arttıkça sahip olduğu kinetik enerji de artar.
>
> **Potansiyel Enerji:** Kinetik enerjinin dışında bir de cisimlerin konumlarından ve esnekliklerinden dolayı sahip olduğu potansiyel enerjileri vardır. Hareket hâlinde olmasa da cisimlerin bazı konumlarından ve esnekliklerinden dolayı sahip olduğu enerjiye potansiyel enerji denir. Potansiyel enerjinin de çekim potansiyel enerjisi ve esneklik potansiyel enerjisi olmak üzere iki kısımda incelendiği açıklanır. Belirli bir yükseklikte olan cisimlerin çekim potansiyel enerjisi varken esnek maddelerin esnekliğinden dolayı sahip olduğu esneklik potansiyel enerjisi vardır. Çekim potansiyel enerjisi cismin ağırlığına ve bulunduğu yüksekliğe bağlıdır. Cisimlerin ağırlığı ve bulunduğu yükseklik arttıkça çekim potansiyel enerjileri de artar. Esnek cisimlerin gerilmesi ya da sıkıştırılması sonucu sahip olduğu enerjiye esneklik potansiyel enerjisi denir. Yayın cinsi, kalınlığı, boyu, gerilme miktarı esneklik çekim potansiyel enerjisini etkiler.

Enerji, iş, enerji çeşitleri olan kinetik ve potansiyel enerji ile ilgili bilgiler verildikten sonra, buna yönelik mühendislik tasarım sürecini kapsayan bir proje tasarlamaları için öğrenciler motive edilir *(Kazanım 7.3.2.2.).* Öğrencileri problem tespiti yapmaya yöneltmek amacıyla aşağıdaki senaryoyu verir.

Bir zamanlar, tüm hayvanların dostça ve huzurlu bir şekilde yaşadığı büyük bir orman varmış. Fakat son zamanlarda bu ormanda yaşayan birkaç hayvan arasında sürekli kavga çıkar ve ormanda büyük bir huzursuzluk hakim olur. Ormanda yaşayan diğer hayvanlar bu sorun için bir çözüm arayışına girerler, bir araya gelerek akıllarına gelen fikirleri paylaşırlar. Birçok çözüm önerisinden sonra ormanın kralını seçmeye karar verirler. Kavga eden at, zürafa, tilki, ayı, kartal ve yılan arasından birini ormanın kralı seçeceklerdir. Bu durumu kavga eden bu hayvanlara açıklarlarve onlar da kabul eder. Peki bu seçim nasıl olacak? Kavga eden altı hayvan kendi kulesini inşa edecek ve onlara verilen topu kulelerinin en yüksek noktasından yere bırakacaklar. Böylece topun yere ulaştığında hızı en fazla olan hayvan ormanın kralı olacak ve orman eski huzuruna kavuşacaktır. Ancak, ormanın onlara sağladığı olanaklar kısıtlıdır, bu nedenle en az malzeme kullanarak bu kuleyi inşa etmelilerdir.

Öğretmen, hazırlanmış olan aktivite kağıdını (Appendix-I) dağıtır ve öğrenciler ders sürecinde bu kağıttaki adımları takip eder. Öğrenciler, etkinlik sırasında 4-5 kişilik gruplar halinde çalışır ve kendi aralarında rol dağılımı yaparak her öğrenci görev alır. Öğrenciler, aktivite kağıdında verilen mühendislik tasarım sürecini (Problem Tespiti, Probleme Yönelik Olası Çözümleri Araştırma, En İyi Çözüm ve Model Tasarımı, Test Etme ve Geliştirme) sırasıyla takip eder. Öğrenciler verilen hikayeyi okuyarak, problemin ne olduğunu tespit eder. Her öğrenci kendisini bir hayvana kendi kulesinin tasarımında yardımcı olan birer mühendis olarak düşünür ve verilen hikayede tespit ettikleri problemi bir mühendis olarak çözüm bulmaya çalışır. Öğrencilerden bulunması beklenen problem "Destekledikleri hayvanı ormanın kralı yapabilmek için oyunu kazanabilmesini sağlayan en yüksek, en az maliyetli ve dayanıklı kuleyi tasarlamak" dır çünkü en yüksekten bırakılan topun yere ulaştığındaki hızı en fazla olur. Öğrenciler, buldukları çözümü en az maliyetli ve en dayanıklı ürüne dönüştürmeleri için *(Kazanım 7.3.2.2.)* aktivite kağıdındaki (Appendix-I) gerekli materyal listesini inceler. Tasarım süresince öğrenciler tarafından uyulması gereken bazı sınırlama ve kriterler bulunur. Bunlar;

- Kulenin boyu en az 15 cm olmalı
- Kule fan karşısında en az 10 sn dayanıklılık göstermeli
- Kule tasarımında en az 3 çeşit malzeme kullanılmalı
- Kulenin üstüne tenis topu koyulduğunda kule yıkılmamalı

Her gruba eşit sayıda makas, ip, bant, ve tenis topu öğretmen tarafından temin edilecektir.

Proje amacının problem tespitindeki gibi en dayanıklı, en yüksek ve en az maliyetli kule tasarlamak olduğu bir kez daha açıklanır. En yüksek kuleyi tasarlayan hayvan, topunu kulenin en üst noktasından bırakır ve topu yere ulaştığında hızı en fazla olur. Böylece topunu en büyük hızla yere ulaştırdığından dolayı ormanın kralı olur. Gerekli materyal listesi incelendikten sonra her grup en yüksek, en az maliyetli fakat en sağlam kule tasarımı için gerekli malzemeleri seçer ve bütçelerini hesaplayarak aktivite kağıdındaki (Appendix-I) uygun bölüme yazar. Öğretmen tahtada zamanlayıcı açarak projelerini 45-50 dakikalık sürede ürünlerini tasarlamalarını ister. Öğretmen, ürün tasarımı sırasında gruplar arasında gezerek öğrencilerin ürünlerini, süreci gözlemler ve rehberlik eder.

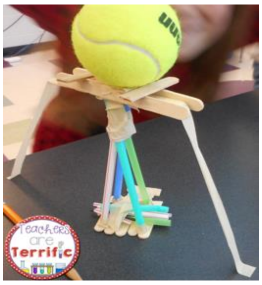
Öğretmen, projeleri test etmek amaçlı sınıfta herkesin görebileceği uygun bir yere malzeme listesinde yer alan fanı yerleştirir. Ürün tasarımı süresi bittikten sonra her gruptan bir öğrenci projelerini tanıtır ve fandan aynı uzaklıkta yerleştirilmiş olmasına ve fanın şiddetinin aynı olmasına dikkat edilerek tenis topunun düşmediği ürünlerinin dayanıklılığı kontrol edilir. Fan karşısında en uzun, en az maliyetli ve en uzun süre dayanıklılık gösterme kriterleri göz önünde bulundurularak her grubun toplam puanı Tablo.1'deki değerlendirmeye göre hesaplanır. Örneğin; 4 çeşit malzeme kullanılarak 15 TL maliyetinde ve 20 cm uzunluğundaki kule fan karşısında 30 saniye dayanıklılık göstermiş ise puanı 3+2+3+3=11 dir. Böylece puanı yani dayanıklılığı en fazla olan ürünün sahibi grup en başarılı grup seçilir.

Puan	**Kulenin Boyu**
3	>20 cm
0	15-20 cm
Puan	**Dayanıklılık Süresi**
3	> 20 sn
2	15-20 sn
1	10-15 sn
Puan	**Malzeme Çeşidi**
3	3-4 çeşit malzeme kullanıldı
1	5-6 çeşit malzeme kullanıldı

Puan	Maliyetimiz
3	0-10 TL
2	11-20 TL
1	21-30 TL

Tablo.1

Olası projeler şu şekilde olabilir;




Öğretmen proje tanıtımı ve testi sonrasında her gruba bazı sorular sorar;

- Projenizde neden bu materyalleri kullandınız? Ve materyalleriniz yeterli oldu mu?
- Tasarlamış olduğunuz kule fan karşısında ne kadar süre dayanıklılık gösterdi? Tasarlamış olduğunuz ürünün sonucundan memnun musunuz?
- Değişiklik yapsaydın daha uzun süre durabilmesi için neleri değiştirirdin?
- Tasarımınız diğer grupların ürününden farklı oldu mu? Neden?

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APPENDIX – H

KULE TASARIMI AKTİVİTE KAĞIDI

Mühendis Ekibi: ____________________ ____________________

____________________ ____________________

____________________ ____________________

Senaryo:

Bir zamanlar, tüm hayvanların dostça ve huzurlu bir şekilde yaşadığı büyük bir orman varmış. Fakat son zamanlarda bu ormanda yaşayan birkaç hayvan arasında sürekli kavga çıkar ve ormanda büyük bir huzursuzluk hakim olur. Ormanda yaşayan diğer hayvanlar bu sorun için bir çözüm arayışına girerler, bir araya gelerek akıllarına gelen fikirleri paylaşırlar. Birçok çözüm önerisinden sonra ormanın kralını seçmeye karar verirler. Kavga eden at, zürafa, tilki, ayı, kartal ve yılan arasından birini ormanın kralı seçeceklerdir. Bu durumu kavga eden bu hayvanlara açıklarlarve onlar da kabul eder. Peki bu seçim nasıl olacak? Kavga eden altı hayvan kendi kulesini inşa edecek ve onlara verilen topu kulelerinin en yüksek noktasından yere bırakacaklar. Böylece topun yere ulaştığında hızı en fazla olan hayvan ormanın kralı olacak ve orman eski huzuruna kavuşacaktır. Ancak, ormanın onlara sağladığı olanaklar kısıtlıdır, bu nedenle en az malzeme kullanarak bu kuleyi inşa etmelilerdir.

Senaryoyu okudunuz. Tenis topunun hangi durumlarda kinetik ve potansiyel enerjiye sahip olduğunu açıklayınız.

Potansiyel Enerji:

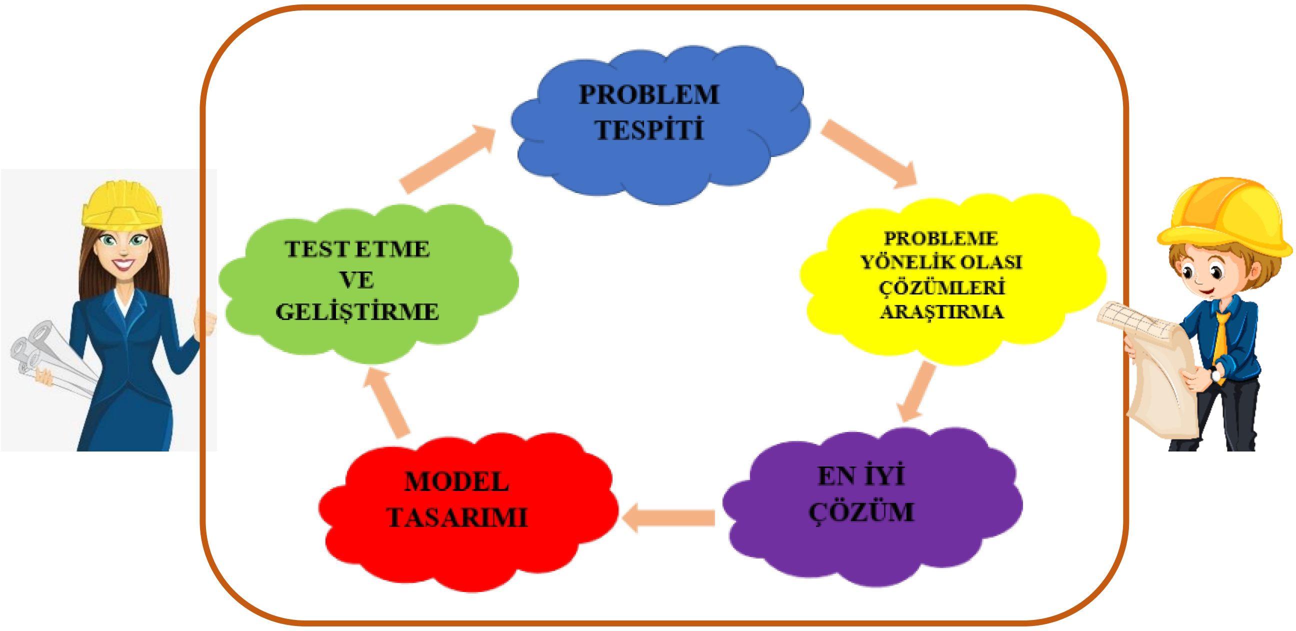
……………………………………………………………………………………………..

Kinetik Enerji:

……………………………………………………………………………………………..

Görev: Senaryoyu okudunuz. Göreviniz mühendis ekibiniz ile kendinizi ormandaki bir hayvanı destekleyen ve kulesinin inşasına yardım eden birer mühendis olarak düşünerek ona yardımcı olmak. Bu görev kapsamında aşağıda belirtilmiş olan "Mühendislik Tasarım Süreci" basamaklarını takip etmeniz beklenmektedir.

MÜHENDİSLİK TASARIM SÜRECİ



A) Problem Tespiti

1. Yukarıda anlatılmış olan hikayedeki problem nedir?

   …………………………………………………………………………………………
   ……….……….………………………………………………………………………
   ………………………………..……………………………………………………..

2. Hikayedeki problemi çözmek için yardım etseydiniz mühendis ekibin ile beraber hangi alanda bir mühendis olmayı tercih ederdin? (Örnek; makine mühendis, inşaat mühendisi, uzay mühendisi vb.)

   ………………………………………………………………………………………….

B) Probleme Yönelik Olası Çözümleri Araştırma

3. Mühendis arkadaşların ile beraber size verilen senaryodaki problemi buldun. Sıradaki görevin, belirlemiş olduğun problemi çözmek için desteklediğin hayvanın ormanın kralı olmasını sağlayacak en az maliyetli ve dayanıklı kuleyi tasarlamak. Burada kulenin boyunu nasıl göz önünde bulundurmalıyız?

   ❑ Kulenin boyu kısa olmalıdır, çünkü

   …………………………………………………………………………………………

   ❑ Kulenin boyu uzun olmalıdır, çünkü

   …………………………………………………………………………………………

   Şimdi size verilmiş olan materyal listesine bakarak tasarımınız için gerekli malzemeleri seçiniz ve toplam tutarınızı aşağıdaki boşluğa yazınız. Fakat bu basamakta mühendis arkadaşların ile beraber çözümleri araştırırken göz önünde bulundurmanız gereken bazı kurallar aşağıda verilmiştir.

- Kulenin boyu en az 15 cm olmalı
- Kule fan karşısında en az 10 sn dayanıklılık göstermeli
- Kule tasarımında en az 3 çeşit malzeme kullanılmalı
- Tasarım sırasında en fazla 30 TL kullanabilirsiniz
- Kulenin üstüne tenis topu koyulduğunda kule yıkılmamalı

Malzeme Listesi

Mühendis Ekibinin Bütçesi: 30 TL

Grupların ortak kullanacakları: Makas, Fan, Bant , Tenis Topu

Her grup kendi tasarımı için;

- Tahta dil çubuğu (0.50 TL/adet)
- Ataş (0.25 TL/adet)
- Oyun Hamuru (1 TL/adet)
- Paket Lastiği (0.20 TL/adet)
- Kağıt (0.10 TL/adet)
- Pipet (0.50 TL/adet)

Malzeme	Tutarı
Örnek: 5 Adet Tahta Dil Çubuğu	5* 0.50 TL = 2.5 TL
TOPLAM TUTAR =	

C) En İyi Çözüm

4. Gruptaki mühendis arkadaşlarınız ile seçtiğiniz malzemeleri göz önünde bulundurarak aşağıdaki kutuya kulenin tasarımınızı çiziniz.

Lütfen kısa cümlelerle çizmiş olduğunuz kule tasarımı hakkında bilgi veriniz.

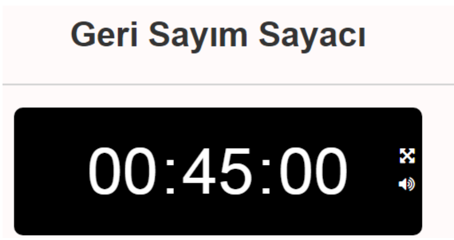
…………………………………………………………………………………………….

………..………...………………………………………………………………………….

……………………………………..…………………………………………………………

D) Model Tasarımı, Test Etme ve Geliştirme

5. Şimdi tasarım zamanı! Tasarım için mühendis arkadaşlarınla birlikte 45 dakikanız var. Seçmiş olduğunuz malzemeleri kullanarak yukarıda çizmiş olduğunuz tasarımı meydana getiriniz.



6. Tasarlamış olduğunuz kulenizin dayanıklılığını öğretmeniniz ve arkadaşlarınız ile beraber test ediniz. Test ettikten sonra gözlemleriniz sonucunda aşağıdaki boşlukları doldurunuz.

Puan	**Kulenin Boyu**	**Puanımız**
3	>20 cm	
0	15-20 cm	
Puan	**Dayanıklılık Süresi**	**Puanımız**
3	> 20 sn	
2	15-20 sn	
1	10-15 sn	
Puan	**Malzeme Çeşidi**	**Puanımız**
3	3-4 çeşit malzeme kullanıldı	
1	5-6 çeşit malzeme kullanıldı	
Puan	**Maliyetimiz**	**Puanımız**
3	0-10 TL	
2	11-20 TL	
1	21-30L	

- Test etme süreci sonunda dayanıklılık gösterme kriterleri ile elde edilen toplam grup puanımız;

  ………… puan

- Kulenizin test edilmesi sonucunda aşağıdaki durumlardan gözlemlemiş olduklarınızı işaretleyiniz.
  - ❑ Gruplar arasındaki en uzun kuleye sahip olan gruptuk.
  - ❑ Gruplar arasındaki en az maliyetli kuleye sahip olan gruptuk.
  - ❑ Fanın şiddetine rağmen kulenin üst kısmında bulunan tenis topu yere düşmedi.
  - ❑ Fanın şiddetine rağmen tasarlamış olduğumuz kule yıkılmadı.

7. Kule tasarımınız sırasında derste öğrenmiş olduğunuz kavramlardan (potansiyel enerji, kinetik enerji, iş vb.) nasıl yararlandınız?

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………………………………..…………………………………………………………

8. Tasarımı bitmiş olan mühendislik projelerinde daha iyi sonuca ulaşmak için gerekli değişiklikler yapılabilir mi? Örneğin, ekip olarak tasarlamış olduğunuz kulenin tasarımından memnun musunuz? Daha başarılı sonuç elde etmek için derste öğrenmiş olduğunuz kavramlardan (potansiyel enerji, kinetik enerji, iş vb.) hangilerinde ne gibi değişiklikler yapmalısınız? Ya da kullanmış olduğunuz malzemelerde değişiklik olması gerekir mi?

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9. Belirli bir problemi çözüme kavuşturmak için "en iyi" ve "tek" tip çözüm var mıdır? Yoksa bulunan çözümler farklılık gösterir mi? Örneğin, ekip olarak tasarlamış olduğunuz kule diğer grupların kulelerinden farklı oldu mu? Farklı olduysa neden farklı, aynı olduysa neden aynı olduğunu açıklayınız.

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10. Tasarlanmış olan bu kule ile tespit etmiş olduğunuz probleme karşı olumlu bir sonuç elde ettiniz mi? Açıklayınız.

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APPENDIX-I

"PARAŞÜT TASARIMI" DERS PLANI

Sınıf Seviyesi: 7. Sınıf

Ünite: 7.3. Kuvvet ve Enerji / Fiziksel Olaylar

Konu: 7.3.3. Enerji Dönüşümleri

Ön Bilgiler: Öğrenciler;

- Kuvvetin tanımı ve birimi *(F.4.3.1. Kuvvetin Cisimler Üzerindeki Etkileri/ F.5.3.1. Kuvvetin Ölçülmesi)*
- Sürtünme Kuvveti *(F.5.3.2. Sürtünme Kuvveti)*
- Kütle ve Ağırlık *(F.7.3.1. Kütle ve Ağırlık İlişkisi)*
- Kinetik enerji, çekim potansiyel enerjisi, esneklik potansiyel enerjisi *(F.7.3.2. Kuvvet, İş ve Enerji İlişkisi)*

Kazanımlar

F.7.3.3.1. Kinetik ve potansiyel enerji türlerinin birbirine dönüşümünden hareketle enerjinin korunduğu sonucunu çıkarır.

F.7.3.3.2. Sürtünme kuvvetinin kinetik enerji üzerindeki etkisini örneklerle açıklar.

F.7.3.3.3. Enerji dönüşümleri ile ilişkilendiren probleme (potansiyel enerjinin kinetik enerjiye dönüştüğü bir paraşüt tasarımı) yönelik üç boyutlu bir proje tasarlar.

F.7.3.3.4. Mühendisliğin doğası yönlerini (mühendislik tasarım süreci, mühendislik kriterleri (demarcation criteria), yaratıcılık (creativity), geçicilik (tentativeness), öznellik (subjectivity)) açıklar.

Kullanılacak Materyal ve Teknoloji Destekleri

- *Bilgisayar ve projeksiyon cihazı, ya da akıllı tahta :* Konu ile ilgili hazırlanmış slaytı öğrencilere göstererek dersin takibini kolaylaştırmak ve proje tasarımı sırasında öğrencilere zaman yönetiminde kolaylık sağlayan zamanlayıcıyı gösterebilmek için kullanılır.
- *Konu ile ilgili hazırlanmış slayt (https://prezi.com/wgf8m_zyprhb/parasut-tasarimi/):* Hem öğretmen hem de öğrenciler için ders takibini kolaylaştıran slayt, konu ile ilgili bir problem, konu ile ilgili video, proje tasarımı için gerekli materyallerin listesi, zamanlayıcı ve olası projelerin görsellerini içermektedir.
- *Simülasyon (https://www.fenehli.com/enerji-donusumleri-simulasyonlari/) :* Öğretmen, kinetik enerji ve potansiyel enerji, enerji dönüşümleri ve enerjinin korunumu durumlarını göstermek amacıyla akıllı tahta yardımı ile bir simülasyon açar.
- *Zamanlayıcı(https://tr.piliapp.com/timer/countdown/#pause=2699545,all=00:45:00):* Proje tasarımı sırasında öğrenciler için süre yönetimi kolaylığı sağlar.
- *Aktivite Kağıdı (EK – 1):* Aktivite kağıdı, proje tasarımı sırasında öğrencilere dağıtılarak hedeflenmiş olan mühendisliğin doğası yönlerini takip etmeyi kolaylaştırır. Aktivite kağıdında “mühendislik tasarımı süreci” adımlarını (problem tespiti, probleme yönelik olası çözümleri araştırma, en iyi çözümü bulma, ve modeli tasarlama, test etme ve geliştirme) ve diğer mühendisliğin doğası yönlerini (mühendislik kriterleri (demarcation criteria), yaratıcılık (creativity), geçicilik (tentativeness), öznellik (subjectivity)) kapsayan sorular içermektedir.

ÖĞRETİM SÜRECİ

Öğretmen, derse öğrencilerin ön bilgilerini hatırlatarak başlar. İş ve enerji kavramları ve günlük hayattan örnekler; enerji çeşitleri (kinetik ve potansiyel enerji (çekim potansiyel ve esneklik potansiyel enerji)) ve örnekler hakkında öğrenciler ile soru-cevap yaparak ön bilgileri hatırlamaları hedeflenir. Hatırlanması beklenen kısa bilgiler öğrencilerden alındıktan sonra öğretmen tarafından hazırlanmış olan slaytta da verilir.

Öğrencilerin ön bilgileri alındıktan sonra öğretmen, doğada bulunan helikopter tohumlarının (helicopter seeds) resmini göstererek bunlar hakkında bilgileri olup olmadığını sorar.

Sonrasında helicopter tohumlarının ağaçların yapmış olduğu rüzgarlar nedeni ile yere düşerken üzerlerindeki tohumları yere düşürmeleri ile ilgili video izletir. Ağaç dalında asılı halde bulunan helikopter tohumlarının ilk olarak çekim potansiyel enerjilerinin olduğu, fakat yere düşmesi sırasında kinetik enerjilerinin olduğu öğrencilere açıklanır.

Daha sonra öğretmen, akıllı tahtada potansiyel ve kinetik enerji, enerji dönüşümleri ile ilgili bir simülasyon açar. Öğretmen ilk olarak kendisi gösterir, sonrasında sınıftan bir öğrencinin yardımı ile sınıfça alıştırma yapılır. Bu simülasyonda öğrenciler kinetik ve potansiyel enerji türlerini ve birbilerine dönüşümünü gözlemleyerek enerji korunumunu kavrar.

Örnekte de görüldüğü gibi, bir cismin sahip olduğu potansiyel enerji ya da kinetik enerjinin birbirine dönüşebildiği açıklanır *(Kazanım 7.3.3.1.).* Enerjinin yok olmadan bir türden başka bir enerji türüne dönüştüğü ve buna enerji dönüşümü dendiği açıklanır. Ve aynı zamanda enerji türünün adı değişse de cismin sahip olduğu toplam enerjinin korunduğu ve buna enerjinin korunumu olarak adlandırıldığı açıklanır. Günlük yaşamdan örnekler verilir. Örneğin; barajda biriktirilen suyun, yüksekliğinden dolayı sahip olduğu çekim potansiyel enerjisinin kapaklar açıldıktan sonra suyun aşağıya doğru akmasından dolayı suyun potansiyel enerjisinin azalarak süratinin artmasından dolayı kinetik enerjisinin artması, ya da bir futbolcunun futbol topuna vurduğunda top yükselirken topun potansiyel enerjisinin artması fakat kinetik enerjisinin azalması veya top yere düşerken de yüksekliği azaldığı için topun potansiyel enerjisinin azalırken sürati arttığı için kinetik enerjisinin artması vb.

Enerji dönüşümlerine ek olarak, kinetik enerji üzerine etkisi olan sürtünme kuvvetinden bahsedilir *(Kazanım 7.3.3.2.).* Sürtünme kuvveti, hareketli cisimlerin süratini azaltarak cisimlerin yavaşlamasına ya da durmasına sebep olur şeklinde açıklanır. Örneğin; bir topa vurulduğunda belirli bir süre sonra topun durduğu çünkü süratle hareket eden ancak sürtünme kuvvetinin etkisiyle topun sürati azalır ve kinetik enerjisi azalmaya başlar. Sürtünme kuvveti olan su direncine ise belli bir hızla giden sürat teknelerinde motor kapatıldığında teknenin bir süre sonra durması örneği verilir. Bunun sebebinin ise suyun tekneye uyguladığı sürtünme kuvveti olan su direncidir, bu nedenle su direncini azaltmak için teknelerin uç kısımları sivri yapılması açıklanır. Sürtünme kuvveti olan hava direncine ise yere hızla çarpmasını engelleyen paraşüt örneği verilir. Hava sürtünmesi olan hava direncinin paraşütçünün süratinin artmasına engel olarak paraşütçünün kinetik enerjisi artmasını engeller ve paraşütçü sert bir iniş yapmamış olur olarak açıklanır.

Enerji dönüşümleri ile ilgili bilgiler verildikten sonra, buna yönelik mühendislik tasarım sürecini kapsayan bir proje tasarlamaları için öğrenciler motive edilir *(Kazanım 7.3.3.3.)*. Öğrencileri problem tespiti yapmaya yöneltmek amacıyla aşağıdaki senaryoyu verir.

> *Bir zamanlar, tüm hayvanların dostça ve huzurlu bir şekilde yaşadığı küçük bir kasaba varmış. Bu kasabada yaşayanlardan biri de yumurtasından çıkmasını beklediği minik civcivi ile yaşayan tavukmuş. Kasabanın bir de sinsi ve kurnaz bir tilkisi varmış. Bir gün bu tavuğun kulübesine bu sinsi tilki girmiş çünkü amacı yumurtayı çalıp kendine akşam yemeği yapmakmış. Anne tavuk ne yapıp edip yumurtasını evden kaçırmalı tilkiye yem etmemeliymiş. Düşünmüş düşünmüş… Ve o an aklına bir çözüm yolu gelmiş. Hemen bir paraşüt yapmalı ve yumurtasını paraşütün içine yerleştirerek onu kulübeden uzaklaştırmalıymış. Fakat bu paraşüt öyle bir paraşüt olmalıymış ki yumurtayı sağlam bir şekilde yere indirmelidir. Ancak, anne tavuğun evindeki malzemeler paraşüt yapmak için sınırlıdır, bu nedenle en az malzeme kullanarak bu paraşütü tasarlamalıdır.*

Öğretmen sonrasında hazırlanmış olan aktivite kağıdını (Appendix-K) dağıtır ve öğrenciler ders sürecinde bu kağıttaki adımları sırasıyla takip eder. Öğrenciler, etkinlik sırasında 4-5 kişilik gruplar halinde çalışır ve kendi aralarında rol dağılımı yaparak her öğrenci görev alır. Öğrenciler, aktivite kağıdında verilen mühendislik tasarım sürecini (Problem Tespiti, Probleme Yönelik Olası Çözümleri Araştırma, En İyi Çözüm ve Model Tasarımı, Test Etme ve Geliştirme) sırasıyla takip eder. Öğrenciler verilen hikayeyi okuyarak, problemin ne olduğunu tespit eder. Öğrenciler, kendilerini birer mühendis olarak düşünür ve tespit ettikleri probleme bir mühendis olarak çözüm bulmaya çalışır. Öğrencilerden bulunması beklenen problem "Yumurtayı yere kırılmadan ulaştıran en az maliyetli fakat en dayanıklı paraşütü tasarlamak" dır. Buldukları çözümü en az maliyetli ve en sağlam ürüne dönüştürmeleri için *(Kazanım 7.3.3.3.)* gerekli materyal listesi dağıtılmış olan aktivite kağıdında (Appendix-K) yer almaktadır. Tasarım süresince öğrenciler tarafından uyulması gereken bazı sınırlama ve kriterler bulunur. Bunlar;

- Yumurta yere sağlam bir şekilde ulaşmalı
- Paraşüt tasarımında en az 3 çeşit malzeme kullanılmalı

- Tasarım sırasında en fazla 100 TL kullanabilirsiniz

Her gruba eşit sayıda makas, ip ve bant öğretmen tarafından temin edilecektir.

Proje amacının problem tespitindeki gibi en dayanıklı ve en az maliyetli paraşüt tasarlamak olduğu bir kez daha açıklanır. Yani tasarımdaki amacın dış etmenlere rağmen inşa edecekleri paraşüt içindeki yumurtayı yere kırılmadan ulaştıracak en sağlam ve en az maliyetli şekilde tasarlamak olduğu açıklanır. Gerekli materyal listesi incelendikten sonra her grup, en az maliyetli fakat en sağlam paraşüt tasarımı için gerekli malzemeleri seçer ve bütçelerini hesaplayarak aktivite kağıdındaki (Appendix-K) uygun bölüme yazar. Öğretmen, tahtada zamanlayıcı açarak projelerini 45-50 dakikalık sürede ürünlerini tasarlamalarını ister. Öğretmen ürün tasarımı sırasında gruplar arasında gezerek öğrencilerin ürünlerini, süreci gözlemler ve rehberlik eder.

Ürün tasarımı süresi bittikten sonra, projeleri test etmek amaçlı her gruptan bir öğrenci projelerini tanıtmak için tahtaya çıkar. Her grubun projelerini eşit yükseklikten serbest bir şekilde bırakmalarına dikkat edilir. Belirli yükseklikten bırakılan paraşütlerdeki duruma göre her grubun toplam puanı Tablo.2'deki değerlendirmeye göre hesaplanır. Örneğin; 4 çeşit malzeme kullanılarak yapılan 15 TL maliyetinde olan paraşüt içerisindeki yumurtanın kırılmaması durumunda grubun puanı 3+3+5=11 puandır. Böylece puanı yani dayanıklılığı en fazla olan ürünün sahibi grup en başarılı grup seçilir.

Puan	**Yumurtanın Kırılma Durumu**
5	Kırılmadı
0	Kırıldı
Puan	**Malzeme Çeşidi**
3	3-4 çeşit malzeme kullanıldı
2	5-6 çeşit malzeme kullanıldı
1	7-8 çeşit malzeme kullanıldı
Puan	**Maliyetimiz**
3	0-35 TL
2	36-70 TL
1	71-100 TL

Tablo.2

Olası projeler şu şekilde olabilir;

Öğretmen proje tanıtımı ve testi sonrasında her gruba bazı sorular sorar;

- Projenizde neden bu materyalleri kullandınız? Ve materyalleriniz yeterli oldu mu?
- Tasarlamış olduğunuz paraşüt yumurtayı sağlam bir şekilde yere ulaştırdı mı? Tasarlamış olduğunuz ürünün sonucundan memnun musunuz?
- Değişiklik yapsaydın yumurtanın kırılmaması için neleri değitirirdin?
- Tasarımınız diğer grupların tasarımından farklı oldu mu? Neden?

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APPENDIX-J

PARAŞÜT TASARIMI AKTİVİTE KAĞIDI

Mühendis Ekibi: ____________________ ____________________

____________________ ____________________

____________________ ____________________

Senaryo:

Bir zamanlar, tüm hayvanların dostça ve huzurlu bir şekilde yaşadığı küçük bir kasaba varmış. Bu kasabada yaşayanlardan biri de yumurtasından çıkmasını beklediği minik civcivi ile yaşayan tavukmuş. Kasabanın bir de sinsi ve kurnaz bir tilkisi varmış. Bir gün bu tavuğun kulübesine bu sinsi tilki girmiş çünkü amacı yumurtayı çalıp kendine akşam yemeği yapmakmış. Anne tavuk ne yapıp edip yumurtasını evden kaçırmalı tilkiye yem etmemeliymiş. Düşünmüş düşünmüş… Ve o an aklına bir çözüm yolu gelmiş. Hemen bir paraşüt yapmalı ve yumurtasını paraşütün içine yerleştirerek onu kulübeden uzaklaştırmalıymış. Fakat bu paraşüt öyle bir paraşüt olmalıymış ki yumurtayı sağlam bir şekilde yere indirmelidir. Ancak, anne tavuğun evindeki malzemeler paraşüt yapmak için sınırlıdır, bu nedenle en az malzeme kullanarak bu paraşütü tasarlamalıdır.

Senaryoyu okudunuz. Paraşütün hangi durumlarda kinetik ve potansiyel enerjiye sahip olduğunu açıklayınız. Uygun enerji dönüşümünü seçerek sebebini açıklayınız.

Potansiyel Enerji:

……………………………………………………………………………………………..

Kinetik Enerji:

……………………………………………………………………………………………..

❑ Potansiyel enerji kinetik enerjiye dönüşür, çünkü

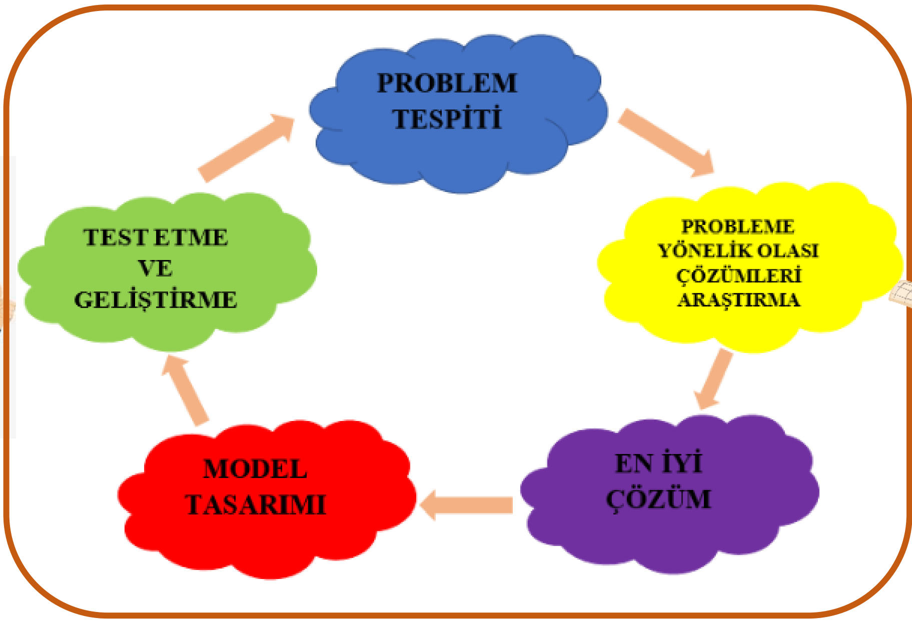
……………………………………………………………………………………………

❑ Kinetik enerji potansiyel enerjiye dönüşür, çünkü

……………………………………………………………………………………………..

Görev: Senaryoyu okudunuz. Göreviniz mühendis ekibin ile kendinizi anne tavuğa yardım eden birer mühendis olarak düşünerek ve ona yardımcı olmak. Bu görev kapsamında aşağıda belirtilmiş olan "Mühendislik Tasarım Süreci" basamaklarını takip etmeniz beklenmektedir.

MÜHENDİSLİK TASARIM SÜRECİ



A) Problem Tespiti

1. Yukarıda anlatılmış olan hikayedeki problem nedir?

   ………………………………………………………………………………………
   ………..………..……………………………………………………………………
   ………………………………..…………………………………………………..

2. Hikayedeki problemi çözmek için yardım etseydiniz mühendis ekibin ile beraber hangi alanda bir mühendis olmayı tercih ederdin? (Örnek; makine mühendis, inşaat mühendisi, uzay mühendisi vb.)

   ……………………………………………………………………………………….

B) Probleme Yönelik Olası Çözümleri Araştırma

3. Mühendis arkadaşların ile beraber size verilen senaryodaki problemi buldun. Sıradaki görevin, belirlemiş olduğun problemi çözmek için yumurtayı yere sağlam şekilde ulaştıran en az maliyetli fakat en sağlam paraşütü tasarlamak. Burada sürtünme kuvveti olan hava direncini nasıl göz önünde bulundurmalıyız?

   ❑ Hava direnci az olmalıdır, çünkü

   ………………………………………………………………………………………

   ❑ Hava direnci fazla olmalıdır, çünkü

   ………………………………………………………………………………………

   Şimdi size verilmiş olan materyal listesine bakarak tasarımınız için gerekli malzemeleri seçiniz ve toplam tutarınızı aşağıdaki boşluğa yazınız. Fakat bu basamakta mühendis arkadaşların ile beraber çözümleri araştırırken göz önünde bulundurmanız gereken bazı kurallar aşağıda verilmiştir.

- Yumurta yere sağlam bir şekilde ulaşmalı
- Paraşüt tasarımında en az 3 çeşit malzeme kullanılmalı
- Tasarım sırasında en fazla 100 TL kullanabilirsiniz

Malzeme Listesi

Grup Bütçesi: 100 TL

Grupların ortak kullanacakları: Makas, İp, Bant, Yumurta

Her grup kendi tasarımı için;

- Kürdan (2 TL/adet)
- Poşet (15 TL/adet)
- Pipet (3 TL/adet)
- Paket Lastiği (5 TL/adet)
- Makarna (3 TL/adet)
- Plastik Bardak (10 TL/adet)
- Balon (20 TL/adet)
- Kağıt (6 TL/adet)

Malzeme	Tutarı
Örnek: 5 Adet Kürdan	5* 2 TL = 10 TL
TOPLAM TUTAR =	

C) En İyi Çözüm

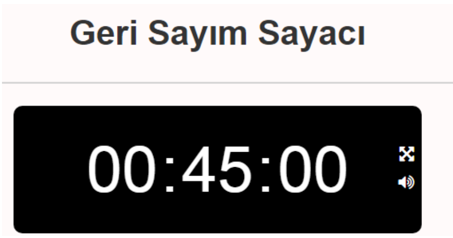
4. Gruptaki mühendis arkadaşlarınız ile seçtiğiniz malzemeleri göz önünde bulundurarak aşağıdaki kutuya paraşütün tasarımınızı çiziniz.

Lütfen kısa cümlelerle çizmiş olduğunuz paraşüt tasarımı hakkında bilgi veriniz.

……………………………………………………………………………………
………….……..……….………………………………………………………
…………………..…………………………………..…………………………
……………………………

D) Model Tasarımı, Test Etme ve Geliştirme

5. Şimdi tasarım zamanı! Tasarım için mühendis arkadaşlarınla birlikte 45 dakikanız var. Seçmiş olduğunuz malzemeleri kullanarak yukarıda çizmiş olduğunuz tasarımı meydana getiriniz.



6. Tasarlamış olduğunuz paraşütünüzün dayanıklılığını öğretmeniniz ve arkadaşlarınız ile beraber test ediniz. Test ettikten sonra gözlemleriniz sonucunda aşağıdaki boşlukları doldurunuz.

Puan	**Yumurtanın Kırılma Durumu**	**Puanımız**
5	Kırılmadı	
0	Kırıldı	
Puan	**Malzeme Çeşidi**	**Puanımız**
3	3-4 çeşit malzeme kullanıldı	
2	5-6 çeşit malzeme kullanıldı	
1	7-8 çeşit malzeme kullanıldı	
Puan	**Maliyetimiz**	**Puanımız**
3	0-35 TL	
2	36-70 TL	
1	71-100 TL	

- Test etme süreci sonunda en az maliyetli ve yumurtanın kırılıp kırılmama kriterleri ile elde edilen toplam grup puanımız;

  ………… puan

➢ Paraşütünüzün test edilmesi sonucunda aşağıdaki durumlardan gözlemlemiş olduklarınızı işaretleyiniz.

- ❑ Gruplar arasındaki yumurtayı sağlam şekilde yere ulaştıran gruplar arasındaydık.
- ❑ Gruplar arasındaki en az maliyetli paraşüte sahip olan gruptuk.

7. Paraşüt tasarımınız sırasında derste öğrenmiş olduğunuz kavramlardan (potansiyel enerji, kinetik enerji, hava direnci vb.) nasıl yararlandınız? Enerji dönüşümü durumu oldu mu? Eğer olduysa hangi enerji dönüşümü gerçekleşti?

   ………………………………………………………………………………
   …….……….……….………………………………………………………
   …………………..………………………………..…………………………
   ………………………………………………………….………………

8. Tasarımı bitmiş olan mühendislik projelerinde daha iyi sonuca ulaşmak için gerekli değişiklikler yapılabilir mi? Örneğin, grup olarak tasarlamış olduğunuz paraşütün tasarımından memnun musunuz? Daha başarılı sonuç elde etmek için derste öğrenmiş olduğunuz kavramlardan (potansiyel enerji, kinetik enerji, hava direnci vb.) hangilerinde ne gibi değişiklikler yapmalısınız? Ya da kullanmış olduğunuz malzemelerde değişiklik olması gerekir mi?

   ………………………………………………………………………………
   …….……….……….………………………………………………………
   …………………..………………………………..…………………………
   ………………………………………………………….……………………..

9. Belirli bir problemi çözüme kavuşturmak için “en iyi” ve “tek” tip çözüm var mıdır? Yoksa bulunan çözümler farklılık gösterir mi? Örneğin, grup olarak tasarlamış olduğunuz paraşüt diğer grupların paraşütlerinden farklı oldu mu? Farklı olduysa neden farklı, aynı olduysa neden aynı olduğunu açıklayınız.

………………………………………………………………………………………

…….………..………..………………………………………………………

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………………………………………………………………..………………

10. Tasarlanmış olan bu paraşüt ile tespit etmiş olduğunuz probleme karşı olumlu bir sonuç elde ettiniz mi? Açıklayınız.

………………………………………………………………………………………

…….………..………..………………………………………………………

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………………………………………………………………..………………

APPENDIX-K

Öğretim Süreci Gözlem Raporu

Öğretmen: **Sınıf Düzeyi:**

Dersin Konusu: **Tarih:**

1. Derse/konu anlatımına başlama:

- ☐ Önceki konu/kavramlar ile bağlantı kurma
- ☐ Öğrencilerin derse/konuya ilgisini artırma

2. Dersin amaç ve içeriğini vurgulamak için yapılanlar:

- ☐ Doğrudan açıklama
- ☐ Öğrencilerin keşfetmesini sağlama
- ☐ Öğrenci merkezli aktiviteler
- ☐ Diğer yollar (tanımlayınız)…………………………………………………………………

3. Ders sürecinde kullanılan öğretim stratejileri:

- ☐ Düz anlatım
- ☐ Tartışma
- ☐ Görsel ve işitsel destekli sunum
- ☐ Gösteri
- ☐ Öğrenci aktivitileri
- ☐ Grup çalışması

4. Derste verilen fen kavramlarının:

- ☐ Günlük yaşamla ve öğrencilerin ilgi alanlarıyla ilişkilendirilmesi
- ☐ "Mühendislik Tasarım Süreci" ile ilişkilendirilmesi

5. Ders sürecinde kullanılan araç-gereçler:

- ☐ Ders kitapları
- ☐ Ek kaynak kitaplar
- ☐ Çalışma yaprakları
- ☐ Filmler
- ☐ Bilgisayarlar
- ☐ Ses ve video kayıtları
- ☐ Somut araç-gereçler
- ☐ Slaytlar
- ☐ Örnekler ve modeller
- ☐ Diğer (tanımlayınız)………………

6. Dersin bitirilmesi;

- [ ] Özet
- [ ] Elde edilen son ürün /projelerin test edilmesi ve yeniden düzenlenmesi
- [ ] Konuyla ilgili ödev verilmesi

APPENDIX-L

APPENDIX-M

APPENDIX-N

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UNIVERSITY OF NEVADA, LAS VEGAS

June 8, 2019

To Whom It May Concern,

Any researcher who would like to use the Views of Nature of Engineering (VNOE) questionnaire can do so with the following citation.

Yesilyurt, E., Deniz, H., & Kaya, E. (2019, January). *Improving upper elementary students' nature of engineering views with an engineering design experience*. Paper presented at the annual meeting of the Association for Science Teacher Education (ASTE), Savannah, Georgia.

Please do not hesitate to contact me if you have any questions or need any additional information from me.

Sincerely,

Ezgi Yesilyurt

Ezgi Yesilyurt, Ph.D. Candidate/Graduate Assistant
Department of Teaching & Learning, CEB 399J
University of Nevada, Las Vegas
4505 Maryland Parkway, Box 453005
Las Vegas, NV 89154-3005
ezgi.yesilyurt@unlv.edu 702-978-06-36 Office: 702-895-1540

Box 453005 • 4505 S. Maryland Parkway • Las Vegas, NV 89154-3005 • Tel: 702-895-1540 • Fax: 702-895-4898
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APPENDIX-O

>> <berna.aydogan@metu.edu.tr> adresine sahip kullanıcı 17 Eki 2018 Çar, 22:47
>> tarihinde şunu yazdı:
>>
>>> Sayın Bekir Hocam,
>>>
>>> Ben Berna Aydoğan. Orta Doğu Teknik Üniversitesi Matematik ve Fen
>>> Bilimleri Eğitimi Bölümü/Fen Bilimleri Eğitimi programı yüksek lisans
>>> öğrencisiyim. Prof. Dr. Jale Çakıroğlu danışmanlığında "The Effects of
>>> Engineering Design Based Activities On Students' Nature of Engineering
>>> View and Motivation" adlı tez çalışmamı yürütmekteyim. "Adaptation of
>>> STEM Attitude Scale to Turkish" adlı çalışmanızı inceleme fırsatım
>>> oldu. Jale Hoca sayesinde "Ortaokul Öğrencilerinin STEM'e (S-STEM)
>>> Karşı Tutumu" adlı ölçeği de inceledim. Bu ölçeği kendi tez çalışmamda
>>> referans vermek kaydıyla izninizle kullanmak istiyorum. Yardımcı
>>> olursanız mutlu olurum, iyi çalışmalar.
>>>
>>> Saygılarımla,
>>> Berna AYDOĞAN
>>>
>>>

>>>
>>
>> --
>> Yrd. Doç. Dr. Bekir YILDIRIM
>> Muş Alparslan Üniversitesi, Eğitim Fakültesi
>> Fen Bilgisi Öğretmenliği
>> Tel: 0553 622 21 16

22.10.2018 Re: "Ortaokul Öğrencilerinin STEM'e (S-STEM) Karşı Tutumu" Ölçek İzini

Tarih: 21-10-2018 [22:30:57 +03]
Kimden: bekir yıldırım <bekir58bekir@gmail.com>
Kime: berna.aydogan@metu.edu.tr
Konu: Re: "Ortaokul Öğrencilerinin STEM'e (S-STEM) Karşı Tutumu" Ölçek İzini

Sayın hocam ölçeği etik kurallar dahilinde kullanmanızda hiçbir sakınca bulunmamaktadır.

TEZ İZİN FORMU / THESIS PERMISSION FORM

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Sosyal Bilimler Enstitüsü / Graduate School of Social Sciences	
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Enformatik Enstitüsü / Graduate School of Informatics	
Deniz Bilimleri Enstitüsü / Graduate School of Marine Sciences	

YAZARIN / AUTHOR

Soyadı / Surname : AYDOĞAN
Adı / Name : BERNA
Bölümü / Department : MATEMATİK VE FEN EĞİTİMİ / FEN EĞİTİMİ

TEZİN ADI / TITLE OF THE THESIS (**İngilizce** / English) : THE EFFECTS OF ENGINEERING DESIGN BASED INSTRUCTION ON 7TH GRADE STUDENTS' NATURE OF ENGINEERING VIEWS AND ATTITUDES TOWARDS STEM

TEZİN TÜRÜ / DEGREE**:** **Yüksek Lisans** / Master [X] **Doktora** / PhD [ ]

1. **Tezin tamamı dünya çapında erişime açılacaktır. /** Release the entire work immediately for access worldwide. [ ]
2. **Tez iki yıl süreyle erişime kapalı olacaktır.** / Secure the entire work for patent and/or proprietary purposes for a period of **two year. *** [ ]
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***** *Enstitü Yönetim Kurulu Kararının basılı kopyası tezle birlikte kütüphaneye teslim edilecektir.*
A copy of the Decision of the Institute Administrative Committee will be delivered to the library together with the printed thesis.

Yazarın imzası / Signature .... **Tarih** / Date ....